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Human Factors in Mechanized Warfare

RICHARD E. SIMPKIN

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To the memory of General George S Patton, Jr.,
"the only Allied general who dared exceed the
safety limits in the endeavor to win a decision"*
(and who might turn in his grave at some of the
notions expressed in this book!)

*An assessment made by von Speidel when serving as Rommel's Chief of Staff, quoted by Esame, H; **Patton the Commander**, London, Batsford (1974)

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This book is maybe more deeply rooted in personal experience and thought than its predecessors, but while writing it I have been continually stimulated by the increasing flow of professional feedback from a number of countries in response to my earlier books and articles. Particularly refreshing were the discussions with my old friend Sven Berge and other Swedish experts in government and industry during a lecture tour in that country. As I see it, the role of a writer like myself is to spark new thinking and controversy; thus I can truly say that criticism is just as welcome and valuable as praise or agreement.

Preface

When I received Richard Simpkin's request to write the "Preface" for his latest distinguished work, *Human Factors in Mechanized Warfare*, I at once informed him that I would do my best to set the stage for what I believe to be a very comprehensive and unusual literary effort. I am intrigued with the challenges he places before the reader, since his prime intention is to convince soldiers, the community of design engineers, and our civilian leadership to look squarely at the hazards of the next war and its impact on the ground mobile arm.

In the pages that follow, there are many significant facets well worthy of careful thought. I will have more to say about them as I proceed. However, to my mind, the outstanding aspect of this particular work lies in Brigadier Simpkin's analysis of the armor or mechanized crewman, together with the people and hardware found within an armored or mechanized system whose role is to provide that crew with the sorely needed support for survival and victory on some future battlefield.

While commanding the United States 2d Armored Division at Fort Hood, Texas, a few years ago, I came daily closer to accepting and eventually advocating the notion of the "systems approach" to my particular branch. I am now a total convert to this thesis. When most of us think of a tank unit, a company, for example, we visualize about sixteen or seventeen tanks either moving on a trail or traversing a piece of ground toward an objective. This force is normally followed by a bare minimum of supporting echelons: maintenance, a supply truck, a couple of fuel trucks and a retriever-type vehicle, all shepherded by an executive officer and the ever-present 1st Sergeant. We do not often concern ourselves with that which frequently trails, sight unseen, behind the forward element as it moves to contact. As many of us are aware, there is a considerable mass of machinery and people following along, whose mission is to keep the company operational.

Battalion (or squadron (1)), brigade (or regiment), division and, in most cases, corps and higher are all part and parcel of the "armor/mechanized system". They must have compatible equipment fully capable of supporting, fueling, servicing, repairing, evacuating and moving that company (without or without attachments) and others like it, to include both people and equipment. Fueling vehicles must be able to keep up with and, when called, promptly join the company. Retrievers must be able to retrieve, repair and extract, in all types of weather and terrain. Engineers must have both the equipment and the

professional competency to assist in general movement, attack, defense or retrograde, and all concerned must be able to communicate with one another and with the supported unit at all times. These follow-on forces must be totally responsive to valid combat requirements, thus making the supported unit truly combat effective. What I describe here, then, is not a series of separate units (a maintenance company, a medical company, a communications platoon, a truck company and so forth). Conversely, this following mass of troops and equipment is an important portion of an armor/mechanized system, without which it can neither move nor shoot nor communicate. A basic understanding of this integrated force spells combat power, and it is with this ingredient that hills are taken, rivers crossed and enemies killed or captured.

Now, the concept which I have described appears absurdly obvious, and so it is. However, it is somewhat saddening to realize that we have been, and are now, far from perfect in this area. There are many reasons for this shortcoming which are beyond the scope of this preface, but which have severely damaged our battle effectiveness through the years. In my view, the systems approach to the development of coordinated and carefully integrated armor/mechanized forces will open many doors to the priceless goal which it is our sacred duty to seek - simply, success in war. Thus, we must finally visualize a force or system containing people and things whose parts must be totally compatible, one with the other. It must be disciplined, responsive to combat unit requirements and reliable when times are hard. It must enjoy a degree of redundancy which permits it to function with losses. From front to rear and flank to flank, it must train vigorously to support, to service, or to fight as a team under extreme conditions of weather, terrain, hostile opposition and, unfortunately, political considerations, while relentlessly pursuing a prescribed objective.

The author's influence in this area is both profound and compelling. In keeping with the title of his book, Simpkin's approach, on the "people" side, literally encompasses every facet of administration and training, and, ultimately, includes fighting and killing. His exposition is complete and thought provoking. As the reader turns each page, he will observe the generation of thought about the unthinkable. In an early chapter, Brigadier Simpkin comes to grips with the preponderance of implications of the armor/mechanized team in a chemical, biological, and radiological environment. Following his analysis of what we are possibly destined to face in this scenario, he calls for acceptance of the additional characteristics of "fightability" and "habitability" to be listed as basic design parameters. Freely admitting that these two characteristics are in opposition to one another, his prevailing counter-argument is simply that following long periods of "buttoned up" confinement, an unfit crew will not be a fighting crew, notwithstanding their aggressive motivation. As a consequence, vehicle habitability must play a major role.

Many readers will not agree with certain of the suggestions advanced under these headings, especially habitability, since Simpkin's thoughts in some areas are quite unusual and, were they to be implemented, costly. But it must follow that reader agreement or disagreement concerning, for example, his suggestions on underclothes for crews which must remain confined for several days, makes little difference at this point in time. What is important is the fact that the author has faced up to the full spectrum of challenges involving extended "buttoning up" in a hostile chemical scenario, and has offered solutions to problems posed by that scenario. Replenishment actions, refueling, the removal of human waste, washing, changing clothes, literally all the necessary physical functions of the ground combat soldier are addressed and discussed. Thus, it must be up to the critic either to challenge or to accept these thoughts. Those prone to challenge, however, (and in some instances I join

that group) are automatically charged to propose feasible alternatives.

On almost every page, the author sounds the call for action by those of us who take pride in standing firm against Soviet expansionism. What of the threat of an immediate and sustained chemical attack in which persistent nerve agents are employed? Could we live and continue our bodily functions under all climatic conditions, after having been warned time and again that the Red Army will adopt chemical alternatives as the going gets tough? Could we prevent dehydration and disease? Could we exist for long periods in our currently issued protective clothing? Considering only the tank crew in isolation, how long could it remain enclosed and still be able to fight? What are the requirements and the limits? What needs to be done to meet that requirement? Let those equal-rights enthusiasts and non-combatant heroes who advocate and approve of male/female tank crews and integrated mechanized rifle squads consider a 96-hour "buttoned up" period with all its distasteful details. The simple act of brushing one's teeth becomes somewhat of an obstacle under such conditions.

Throughout this book, all aspects of the armor/mechanized system, the characteristics of which I have outlined in the foregoing paragraphs, are addressed. Simpkin touches upon tank crews, mechanized infantry squads and the various categories of supporting personnel. Repeatedly, the proposition is advanced that nerve gas casualties must be prevented or otherwise held to an avoidable minimum since their effect on soldier morale will be dissimilar from the effect of conventional wounds; predictably, much more devastating, both physically and psychologically. In the author's words, "...It is highly questionable whether morale can in fact be sustained in face of even the minimum practical casualty level."

The author does not omit the fight. In fact, an entire section of seven chapters is devoted to this fundamental activity, repeatedly emphasizing the mandatory requirement for mental and physical fitness at the outset of battle, together with support, replenishment and maintenance to the end and beyond. He advocates a special brand of person to serve within this system - a long-term service soldier. A policy decision supporting that suggestion would, of course, be met with genuine enthusiasm by those of us who are familiar with the exigencies of this trade. However, assignments of this nature are not probable for most armies, especially under full or partial mobilization conditions. Reflect, if you will, on the multiple wraths of adjutant generals, finance officers, dentists and military policemen, looming like a summer storm across the Army. Oh, perish the thought that these heroic types would forfeit portions of their share of unusually able soldiers to man dusty, greasy fighting and support vehicles of this decisive arm. While it is certain that those elements should be operated by the best we have, the decision will not materialize, and it is simply "dreamland" to think otherwise.

On the other hand, the eternal challenge of all commanders, so well stated by General Bruce Clarke, USA, is to form a superior team (whatever its mission) from a reservoir of average personnel. This is done through a carefully contrived combination of good administration, leadership and performance-oriented training techniques which, although modified as weapons change and improve through the ages, are basically as old as war itself. The adage, "Make them think they can win and they will," continues with a degree of validity. The one ingredient which is practically mandatory in the formation of an effective force, whatever its mission, relates directly to the absence of turbulence. This is especially true when combat vehicle crews are being formed, trained and deployed. I know of nothing more damaging to a tank unit, for example, than to lose more than 60 % of its gunners to the pipeline within a six-month period. This has occurred repeatedly in my service and its

effects on operational readiness are devastating. Then, just as you are recovering, in comes yet another administrative belly punch.

In summary, Richard Simpkin's volume offers important challenges to all who have chosen to involve themselves with the study of combat operations in preparation for a war which promises to be awesome in its dimensions. He has promulgated some very deep and thought-provoking notions on human factors in mechanized warfare, with special emphasis on coping with a hostile chemical environment. He suggests solutions. He offers alternatives and options. He will make you think, and he undoubtedly will provoke discussion and argument from all directions and levels.

Finally, this volume has merit for those who must confront the stark realities of their personal responsibilities for tomorrow's ground combat soldier. This charge cannot be lightly thrust aside, for regardless of technological advances so lately witnessed in both weaponry and associated hardware, that individual retains a solid grasp on his position as the foremost instrument of war. Therefore, it is a refreshing honor to identify and set the stage for a work which examines in considerable detail the ability of the human instrument to train for, to survive, and to be victorious in tomorrow's intensive combat environment.

George S Patton
Major General (US Army, retired)

South Hamilton, Massachusetts

Note

1 British "regiment" (Author)

Introduction

In his review (1) of *Tank Warfare* Major General George S Patton was kind enough to praise the way the book covered the imponderables of a tank's effectiveness, the elements unamenable to objective definition and analysis. In the UK, despite the existence of government R & D establishments, the message has never really been hoisted in by the technologists in these establishments, let alone by the firms responsible for detailed design ("design parents"). In the FRG and the USA, where a far higher proportion of analytical and initiatory work is done in industry, the analysts' and designers' understanding of the man-machine interface is evidently lower still.

I incline to the view, shared I think with many soldiers, sailors and airmen, that the real combat worth of a piece of hardware turns on this interface being right at two levels. One lies in relieving the crew of as much physical effort and as many routine tasks as possible, while fully exploiting the higher brain functions of selection, decision making, bridging data gaps and, sometimes, achieving the impossible - "pulling something out of the bag." The second, more elementary but no less important, is simply making the vehicle as agreeable as possible to live and fight in - minimizing the hate term in the love-hate relationship between man and machine.

Nonetheless *Tank Warfare* was mainly aimed at conveying technology to the user and manager, so that the human factors aspect was dealt with rather sketchily and presented in a somewhat disorganized manner. In *Antitank*, the approach I used tended to shut out the human factors side or at least to assume that the technologist would be aware of it. There is a number of excellent novels about being a tanker in war (2), but these are apt to be dramatized beyond the point of credibility, to pick on the aspects of general interest and to ignore much of the - literally - sordid detail. Additionally they focus mainly on World War II, and quite a few things have changed since then. Much of the published "documentary" material on this topic, in English and German alike, was written by hacks or enthusiasts with no first hand experience - by people who, as MG Patton puts it, "have not been privileged to associate with tank crews over the years." These works are mostly simplistic, wrong in balance if not in fact and of little value to any of the professionals concerned.

By contrast there is a wealth of relevant American and British scientific work of the highest quality, much of it published, in disciplines including applied

and experimental psychology, biotechnology, control engineering, cybernetics and various forms of operational analysis. Much of this, like optimization of instruments, displays and control movements, has found its way into armored vehicles via other fields such as aerospace or automobiles. Direct application of work on sighting optics and reticle patterns, stemming initially from the Third Reich, led to decisive advances in achieved firepower and now provides a spin-off for optronic systems. Again, depth studies of prone and supine driving positions led to the British Chieftain's driver's station and are now finding application in United States projects like HSTV/L (3). An understanding of the response of the human organism to various frequencies and amplitudes of vibration has done much to increase usable cross-country speed. Coming at the same problem another way, the Swedes pioneered protection of the crew against the effects of cross-country travel. These are but a few examples of success stories at the interface of armored vehicle and crew.

These success stories, though, would have been more striking and more numerous if the relationship between the user and scientists working in human factors fields had been a happier one. One problem, which this book seeks to alleviate, is communication. A tougher one still lies in entrenched attitudes on both sides.

Trouble is, there is right on both sides too. A commander who rejected all tradition and experience and followed slavishly the teaching of psychologists and educationists would end up with a bunch of men unmanageable in a combat situation. Conversely experts in those disciplines are mostly quite unable to appreciate or accept the goals and constraints implicit in the realities of combat. This conflict of viewpoints quickly leads to a situation where the soldier rejects all scientific advice concerning human performance or the interaction of man and machine outside conventional medical fields. He disregards impeccable work like that done at Cambridge (England) and other centers on the effects of sleep deprivation and optimum patterns of limited sleep. He may even ignore research carried out under the auspices of his sister services, on endurance and survival for instance.

The results of this attitude are doubly serious. They directly affect doctrine and training; and they prevent the user from bringing pressure on the designer to take account of human factors even where there is no tangible payoff in design terms. If this book makes the odd traditionalist on both sides of the house turn in his grave and arouses roughly equal ire in soldiers and scientists, I shall know I have hit a middle course and helped bridge the gap.

The Soviets seem to have the knack of getting the man-machine interface right; I touched on some of the reasons for this in the Introduction to *Antitank* and shall be developing the theme in a future book. Likewise they publish plenty of excellent material on the subject. All this serves to point the moral to the West but for many objective reasons is of little practical use as it stands.

As we long suspected and now know, the Soviets select very small men as tank crew; the upper limit for T72 is 1.60 m (5 feet 4 inches) and the optimum 1.55 m (5 feet). Western adult males are larger; and as far as I know no Western army has ever attempted selection based on **maximum** size. There are other divergencies too.

> Despite the enormous strides the Soviet Union has taken in education and the development of key vocational skills, limitations in numeracy and technical awareness still present a real though manageable problem. Thus Soviet and Western control engineering philosophies differ in kind as well as in quality.

Although it would be quite wrong to suppose that the Soviet soldier is still likely to go short of rations or medical support, the background and standard of living of their manpower pool leads to much more limited expectations of comfort than are found in the West.

The Warsaw Pact's numerical superiority, along with Soviet teaching on frequent formation reliefs (on which current trends towards a more deliberate concept of operations look to be placing increasing emphasis), means that their armored vehicle crews can accept low standards of comfort without loss of effectiveness.

> As the potential aggressor, the Warsaw Pact can maintain lower states of readiness than NATO needs (Though surely scarcely lower than NATO practices!), avoiding long waiting periods at full combat readiness. More important still, as the potential initiator of chemical and nuclear warfare, the Pact's combat troops have no need to undergo long waiting periods under NBC protection.

The bulk of important Warsaw Pact weapon systems emanate from the USSR and are thus designed to a coherent, almost standardized picture of manpower quality. In 1978 one could write of two levels of technological acceptance and awareness within NATO - one in North America and another in Europe from the Atlantic Coast to the Urals. Now the most prosperous European economies, notably the FRG, the Netherlands, Scandinavia and Switzerland, have promoted themselves to the American league while, for one reason or another, Belgium, Britain, France and the whole of southern Europe are still on square one. One sees this best, maybe, in the standard of medical treatment - a field in which every national economy can be expected to aim at the highest standard it can achieve.

A further and related difference between East and West lies in their technological philosophies. I have discussed this elsewhere but make no apologies for reemphasizing it here. The Soviet approach is essentially conservative and evolutionary. They make their quantum jumps from strong, firmly secured springboards into waters whose depth they have measured. For Western, specially United States, engineers, the caution implicit in respect for Murphy's Laws (4) looks like it has given way to the slogan "If it works, it's obsolete." Unfortunately this rashness goes hand in hand with unceasing efforts to cut or at least contain costs. By contrast the Soviets' stated and real aim is to field the best piece of hardware they can. Taken together with the advantages on the human factors side, these are two of the reasons why Soviet weapon systems tend to be more soundly rationalized than their Western counterparts.

A quite different reason why I disagree with much that is said, written and done about human factors in mechanized warfare is that, in face of pressures which are in the main self-evident, user, biotechnologist (5), analyst and engineer all tend to pan in on the critical situation - the armored vehicle in battle. Just as war is ninety per cent (or some say ninety nine per cent) boredom and ten per cent (or one per cent if you like it) intense fear, so wartime tanking adds up to "ninety per cent" out of contact, living on, moving around in and looking after a vehicle, and "ten per cent" fighting. Aside from the flow of adrenalin, the same goes for peacetime life and tank training. So giving the crew a chance to enter battle physically and morally fit has to be a legitimate user requirement and design goal. It may well be worth trading off some physical performance of material to optimize the achievable battle performance of the total crew-hardware system.

So I want to attempt something that, as far as I know, has not been done before either in published form or in official documentation - to explore in depth the basic facts of a tanker's life and their influence on how he is trained and led and how his machine is designed. By "tanker" here I mean any member of an armored vehicle crew. I shall be addressing mainly analysts and subsystems designers, specially those who may never have seen a tank in the flesh, let alone ridden in one! But we are now at a point in time where very few officers on the active list have experience of sophisticated mechanized operations. So I hope my remarks, based on my own experience and more importantly on trials using battle-experienced crew commanders, may be of some value to the "representative user" and to the young officer and noncom too.

I will extract relevant points from possible European and other scenarios as they arise; but there are two linked assumptions - not unrealistic ones for the nineties, I guess - which underlie my treatment of the subject. The main mechanized maneuver force will still be based on tracked armored vehicles, which we can classify for our present purpose as "small crew" vehicles, presumably weapon and/or sensor platforms, and "large crew" vehicles carrying a maneuver squad or a command and communications team. Second, the basic maneuver unit will be a composite "tank-infantry" battalion of the general kind described in my previous books.

Elgin, Scotland

Richard E Simpkin

Notes

1 **Army** (Journal of the US Army Association), May 1980

2 I am sorry that the term "tankers" gets British readers on their high horse. Maybe they should think again though; otherwise they may soon find themselves having to replace "tank men" by "tankpersons."

3 See **Antitank**, page 131

4 Murphy's Laws on the behaviour of inanimate objects -

1 If it can go wrong, it will.
2 If it can't, it still will.

5 British "ergonomist"

Part 1 Living

CHAPTER 1

Communal Existence and Discipline

Psychologists have made substantial and fruitful contributions to progress at the man-machine interface and to the taming of new control techniques. Along with workers in other medical and paramedical disciplines, they have pitched in constructive advice less fruitful because less widely accepted on human endurance and survival. But few soldiers or successful managers have much regard for the teachings of psychologists, or of sociologists or educationists either, when it comes to human relations. There is a great gulf fixed between the aims and thinking of such scientists on the one hand and practitioners of leadership, training and discipline on the other. So I shall approach the thorny subject of discipline rather simplistically and subjectively, from a line of departure fixed by two observed facts.

One, well known to every officer and singled out by ethologists, economists and multidisciplinary pundits like Anthony Sampson, is the importance of "tribal" structure and tradition. The second factor, more relevant here, is the leader/led ratio and the presence or absence of an object which embodies the common aim and interests of the group. Since an object of this kind increases both the fighting power and the cost of a man, the two factors tend to march hand in hand. Together they suggest a kind of graduation of disciplinary environments -

high performance aircraft (aircrew plus ground crew)
"small crew" armored vehicles
small warships (eg fast patrol boats)
"large crew" aircraft
"large crew" armored vehicles
horsed cavalry
medium and large warships
infantry

Here we can in fact distinguish a third parameter - the physical isolation provided by the "object," and the dependence of the team's lives on the "object." These features should place "large crew" aircraft above small ships, but a further bias is also at work here. Small ships come at the high speed, romantic end of a navy's hardware spectrum, and large aircraft at the ponderous, unromantic extremity of an air force's. Yet again, cultural and social norms of officer selection and noncom promotion, along with terms of service, tend to pull the spread of disciplinary practices in a country's air, land and sea services towards a common center of mass. So we find air force

ground defense units to be more "regimental" than the infantry (1); and, for much better reasons deriving from their origin, the marines of every nationality I know to make even a visitor feel that, welcome as he is, the top joint of a little toe out of place may land him in the brig.

So it is simplistic to talk of "imposed" and "accepted" discipline. If these buzzwords mean anything at all in an environment where **all** leadership is backed by sanctions culminating in deprivation of physical liberty, they are no more than two points on a continuum. The nub of successful discipline is team spirit. Servicemen of all ranks, ages and nationalities naively suppose that this is a natural human trait. Both skippering yachts with nonservice crew members and my work as an intermediary and consultant since leaving the Army convince me that it is not - or if it is, it is not so much a light hidden under a bushel as a glowworm under a haystack. So "disciplinary" training really adds up to developing team spirit and tribal loyalty to the point where the subordinate willingly accepts command authority and feels free to apply his skills and initiative to best effect within this framework.

Traditionalists maintain that the instant blind obedience some situations call for can be assured only by rigorousness, even harshness by a combination of officer mystique and incessant bawling out by noncoms. Many from Sir John Moore onwards disagreed and practiced their heresies as far as they were able. But it took a decade of British experience in Northern Ireland to disprove the value of harshness once and for all. The achievements of armored and artillery units operating as infantry alongside line infantry battalions have been marred only by the miniscule incidence of lapses, absolutely and maybe proportionately fewer in number, and certainly less serious in nature than those occurring within the infantry proper. We can therefore accept the attitudes and practices of US Armor, the Royal Armoured Corps and the Bundeswehr's Panzertruppen as generally valid and use them to examine the special problems of discipline in "small crew" armored vehicles (which for this purpose we can call "tanks" whatever their exact nature) and the interaction of these problems with design.

The trainer of tank crews faces a whole nest of problems. Mastery of the group of single-skill tasks each member must perform stretches most of the men concerned to the limit and beyond. Here one must strike a balance between British worship of simplicity and the American and German conviction that advanced technology makes for ease of operation. (3) Sure, microprocessor-based control engineering enables semiskilled individuals of limited intellect to select and initiate complex programs. At the same time the very nature of these advanced systems combines with the operator's lack of understanding of them to take man out of the primary control loop and so prevent him from "pulling something out of the bag" in emergency. Additionally, at the risk of sounding cynical to those without service experience, I would say that job satisfaction is a key factor both in motivation for training and in battle morale. "Flying" a manually controlled antitank guided missile or hitting a moving target from a moving Centurion was an extremely exciting and satisfying business, leaving little room for fear. I doubt the same is true of launching an autonomous missile or even laying a single-mark electronic reticle on an electronic target image and pressing a button.

I suggest the user can fairly ask the designer to develop systems which make full use of available technology, are within the grasp of the average crewman **and** leave him with an exciting and satisfying job to do. In return the technologist can reasonably expect the user to put a rather higher grade of man into the turret stations (or their future equivalent). We shall see in a moment that there are other reasons for this upgrading. Most armored soldiers, including myself, are opposed to aircrewlike selection for tanks. This is one

reason why in all my books I have come out so strongly for composite units. With crews and maneuver squads in the same platoon the selection base for key crewmen is broadened without stiffening the manpower requirements for the combat arm(s) as a whole or resort to methods of selection apt to breed gladiators.

The second problem area lies in the simultaneous development of "small team" spirit within the crew and tribal loyalties at platoon, company and to a limited extent battalion level. As I have written elsewhere, I believe the large company (200 to 250 strong) to be an ideal higher level focus for loyalty. Conventionally the platoon is the primary focus for junior enlisted men, but in the large composite platoon (of around 50) I reckon it might become the section. (3) I will only touch on this aspect, for practices which seemed radical in the fifties and sixties are by now widely established in many armies; and the designer's sole contribution here is making the hardware "look right." In this approach, all routine parades are held with the crews and maneuver squads standing to their vehicles and with administrative personnel at or just outside their place of work. In this way a quick morning parade linked to daily servicing becomes purposeful. Ceremonial parades should be wholly mounted if possible or at least involve the primary vehicles; by the same token they should be used to bring crew skills to a high pitch of speed and precision.

At the other end of the scale arduous training (now most widely termed "evasion and escape") is carried out by crews acting as a team. Basic "taglike" exercises by crew/squad teams are cheap, easy to set up and can be made interesting with a dash of imagination. They keep men fit and teach cooperation, fieldcraft, an eye for ground in general, and maybe knowledge of the formation's operational sector. Offshore sailing by crews/squads in small boats skippered by the vehicle commander comes much nearer than anything else I know including field exercises to reproduing the psychological environment of a tank crew in war. But it is expensive and may be difficult to arrange. Not all vehicle commanders will be trainable as skippers; but the "escorted cruises" which have become so popular in the leisure field and offer yachtsmen a pleasurable way of upgrading certainly have application here. Mountaineering and langlauf skiing, again by crews/squads, offer a very good compromise between "evasion and escape" and sailing; arduousness can be controlled but the weather is always present as a joker. By contrast specialized rock climbing and downhill skiing are fine for the gladiators but of relatively low crew training value. I studied these questions in some depth back in 1959 (4) and concluded that all these exercises should involve progressively longer periods of self-contained team activity, and that a "rally" type of control and scoring was preferable to any form of overt racing.

The third area, which concerns the designer very deeply, is the distribution and sharing of duties. No tanker is ever going to admit it even to himself; but I suspect many armor commanders at levels from tank to battalion subconsciously resent having the responsibilities of command without the trappings - quite apart from the sheer physical difficulty of commanding anything more than a small platoon from a tank. This problem has been progressively eased by improved communication harnesses and the provision of APC-based command vehicles down to company level. (5) Nonetheless I reckon it has been one of the unstated reasons for the passionate defense by Anglo-Saxon users of the conventional turreted tank. In this configuration, the commander's physically superior position always gives him a wider and deeper view of the scene than his crew, and in full turret defilade he is the only one who can see much at all.

Since this assertion will doubtless be disputed, it is worth underlining with

examples. Despite the glaring and generally agreed need to unburden the tank commander and the great advance in fire control and device represented, user and troop trials of the original "reflector-cum-periscope (RCP)" sight in Centurion evoked considerable resistance on the grounds that it gave the gunner too much responsibility too early. On user insistence the coincidence rangefinder of Conqueror was located in the commander's subturret (result inadequate base length); the initial readout was exclusive to the commander and only passed to the gunner (if the circuit worked!) after "approval" by the commander. Similar resistance by expert arm center users resulted in Chieftain's original fire control system being significantly slower and less flexible than the then state of the art allowed.

The American user insisted on the excrescence of a cupola up at the rear of M60A2's "compact" turret (pl 1), thus making its side aspect the most disastrous slab target in armored vehicle history - or at least pre-compound armor history. (6)

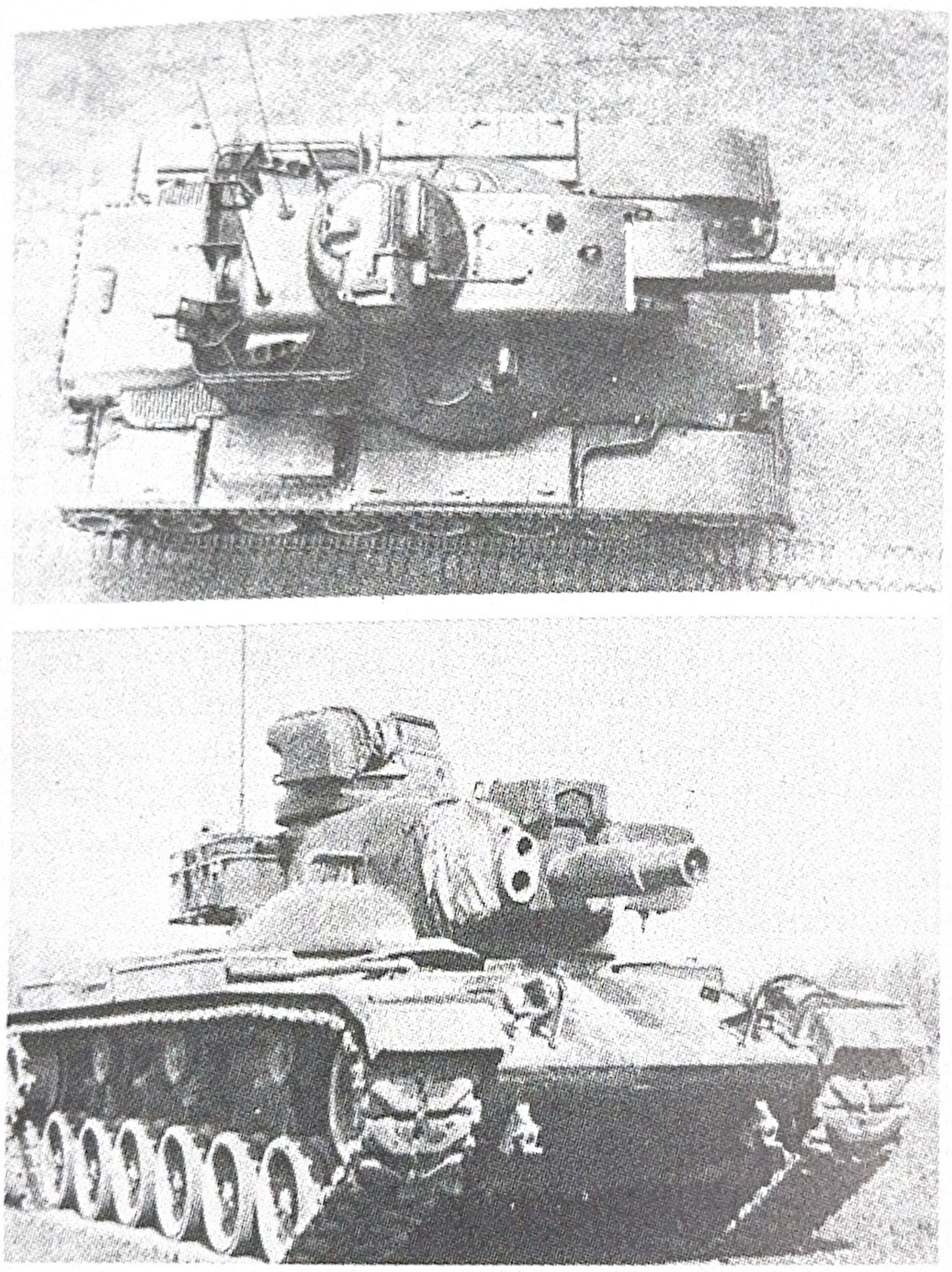

Plate 1. M60A2 (with 152 mm gun-launcher for SHILLELAGH ATGMS)

These two views of the "compact" turret of M60A2 illustrate the excrescence of a cupola (see text), the size and slablike nature of the turret sides, and the isolation of the crew from one another when in their normal stations.

It would seem that the democratic layout of vision and sighting systems and controls was one of the reasons for the British Army's rejection of the S Tank. The Wehrmacht always went for telescopic primary gunner's sights (and very fine instruments they were) and the Bundeswehr opted for a telescope in Leopard 1 in the teeth of Western and (as it turned out later) Soviet trends. Right up to 1971 much British and German user opinion remained opposed to indirect (vidicon-based) vision systems capable of producing multiple displays.

Only the Swedes, it seems, were able to adopt a totally relaxed attitude towards shared vision, overrides and shared or optional crew duties - "the one-man tank with the three-man crew."

It took a doubling of effective range (that is a fourfold increase in the field of observation), depth analysis of target sensing, a sharp pointer from the autoloader of T72 and a new generation of representative users to bring the Americans and Germans at least round to the Swedish point of view. At last there seems to be general acceptance that, whether we are to have a two-man turret, a two-man control console with the hull or a weapon pod slaved to it, or two separate positions, the commander's and gunner's stations will have to be virtually identical. They must be arranged for shared surveillance and easy two-way handover of targets and provided with duplicate facilities including driving override. Evidently a system of inhibit devices and interlocks will be needed so that certain command functions can only receive inputs from one station at a time. But opinion looks to be settling down with the concept of a "one-man tank with a three-man crew." Additionally the need to exploit available fire-control technology and cross-country speed, and to minimize fatigue, will lead to aircraftlike crew stations with contoured seats, rationalized layout and normal reading positions of instruments, and maybe a number of head-up display options available on call.

Whether or not we come to talk of the gunner as "deputy commander," the commander is evidently going to lose his superior position in all senses but one - that he is either of higher rank or has been designated commander. Until fully engineered layouts of this kind with duplicate stations and slaving are available for inspection and trial, it is hard to say what new approach to discipline they will call for. My guestimate, partly based on the strength of earlier user resistance, is that, taking early Centurion or M48 as a reference base, the difference in attitude will need to be almost as marked as that between infantry squad and tank crew. In *Mechanized Infantry* I outlined the most likely path of promotion within a composite platoon and concluded that every turret or command console would come to contain a sergeant and a corporal. I never did think that corporals, specially ceiling corporals, should have command of a tank; the Bundeswehr's *Unteroffizier* (roughly half way between corporal and sergeant) represents around the minimum acceptable standard of man.

I suggest, though, that the designer will need not just to give the designated commander's station normal override over both others in all functions but, even at a slight cost in efficiency, to take positive steps to flatter the commander's ego. The kind of thing I have in mind may be trivial to the point of farce when set out in black and white like giving him a functionally identical but superficially distinctive type of headset or even trimming his seat with superior material. But you only need to see how folks spend money on cosmetic items and individualizing if meaningless stickers for their autos to realize the psychological boost these gimmicks provide. It always struck me that the United States armed forces were remarkably good at this kind of ego-boosting and were prepared to spend money on it. I even recall once hearing somebody refer to SAC as "Strategic Advertising Corporation." (7)

Although I beefed about lack of the trappings of command, most crews look after their vehicle, platoon or company commander very well. Unless my family was on station, I reckoned to live far better on my tank or command vehicle than in post. (But then I always like to describe even the best of officers' messes as "mockeries of luxury.") But the crew commander, whatever level of command he holds, must as a matter of physical necessity and morale share in the chores. As I remarked above, the situation is very like that of a small yacht at sea where (as I at least believe) the skipper should take his turn at

foredeck work, cooking and washing dishes when he is free to do these things. It comes far harder to some than to others, but the problem of coexisting with one's crew simultaneously at two different levels - as boss and as buddy - is a real one which has to be faced. The armored vehicle situation is by far the most difficult. An aircraft crew normally has to be together only when flying; and in small ships there is usually room for some kind of segregation, even if only a bunk to retire to.

All this calls for a high degree of unconscious awareness - if the reader will allow me one of those utterly expressive and precise pieces of Irish - on the part of a crew commander, specially an officer. On the one side of the coin, he will only gain the kind of respect and liking the situation requires by leading by example. On the other he just has to be absolutely ruthless both about leaving his crew whenever his duties require it (whether or not summoned by his superior) and about resting when he needs to. There has to be complete mutual trust and give-and-take without the least impairment of the commander's real authority. This is something far harder to achieve in the everyday chores and rubs of living together than in sharing exciting experiences and heroic deeds. Fear, difficulties and physical effort soon knit a trained team closer. Experience suggests to me that success is at least as dependent on the junior noncom and trained crewman as it is on the commissioned or enlisted vehicle commander. This is one reason why I personally favor finding a high proportion of officers from the ranks, treating the junior career officer as a management trainee who makes his first sustained appearance when he is reasonably trained and mature, and relying almost entirely on officers promoted from the ranks for the performance of routine and specialized duties. (8)

Conversely the creation of an environment in which an appropriate style of cheek-by-jowl living can take place is a major factor in the habitability of an armored vehicle and thus - to say the least - a significant factor in its design. We will be looking in subsequent chapters at particular aspects of this question and at the problem of vehicles with relatively large complements, to my mind a very different one. First though, we need to probe that pair of buzzwords habitability and fightability.

Notes

1 I am basing this remark on observation of the British Royal Air Force Regiment. It is not intended as a criticism, but to an outsider the contrast between this element and the aircrew is very striking to say the least.

2 Feedback from **Tank Warfare** and professional and personal observation over the last two or three years makes me think that the prosperous European economies recently crossed the Atlantic divide with regard to awareness and acceptance of technology (cf. page 2)

3 The introduction of an additional level below platoon posed problems of terminology for me. In **Antitank** I finally opted for platoon - section - crew/squad.

4 When researching a prize essay on "Training for Nuclear War." (See Bibliography).

5 In my previous books I have in fact proposed CSVs (command and support vehicles) down to a (large) platoon.

6 ie blindage composite, Chobham armour, kombinirovannaya bronya, Schottpanzerung, special armor.

7 Strategic Air Command

8 Cf. **Antitank**, Chapter 24

CHAPTER 2

Habitability and Fightability

When conventional armored wisdom focuses on biotechnological aspects at all, it regards habitability as an element in fightability. This is a trap I fell into myself in *Tank Warfare* and is not an easy one to avoid when one is looking at the design of armored vehicles as a whole. By contrast, from examining possible Mideast scenarios in *Antitank* and now panning in on human factors as a topic in its own right, I reckon that, while habitability and fightability have much in common, they may conflict with each other almost as strongly as both do with the other major design parameters of a tank and as those do with one another.

To come to grips with these rather nebulous concepts, we might start by defining **habitability** as the characteristic which brings crews to battle fit after long waiting periods and maybe long moves on their tracks. **Fightability** then means the quality represented by the proportion of the vehicle's across-the-board fighting power that an average fully trained and fit crew can realize. Both these parameters have a high psychological content superimposed on the self-evident physical factors. Maybe the easiest way to discuss them is in terms of a notional trials program.

Though I know of no formal work exactly on these lines, both characteristics should be quite readily quantifiable in relative terms. This process is easier to envision in the case of **fightability**, so maybe we should take that one first. For starters we need to select maybe 6 test characteristics and define them in such a way that user and designer alike regard them as of roughly equal importance - thus ducking the weighting problem. I would suggest these -

achievable average speed on good roads

achievable average cross-country speed

time and precision of movement from turret to hull defilade and back

mean target acquisition time (say 4000 m radius, 150° arc)

hit time (after acquisition, i.e. kill time assuming 100 % lethality)

percentage of available targets acquired/hit on battle run.

To minimize unwanted variables there is a choice between using a number of crews on identical mobility routes, test positions and range setups; and using just a pair of crews - a crack one from a user trials establishment and an average one from a field force unit - on a series of test courses normalized or evaluated for correcting factors by other crews.

We can then establish 5 scores, expressing the 4 practical scores as percentages of the first -

Optimum achievable performance (100 %). To establish this the trials crew only is used. They are fully rested and their vehicle is checked out before each test; they are briefed on it in depth and allowed to "walk the course." Each test is carried out under the most favorable conditions possible of weather and ground.

Fresh trials crew performance. Here the crew starts fully rested with a newly checked out vehicle. Physiological and psychological tests (1) are carried out to establish control figures for subsequent tests. The crew is briefed only on any special peculiarities of the test course used (like where to ford a stream if every course does not include a shallow crossing). In the maneuvering tests and firing runs, other vehicles are used as flank controls and the trials officer acts as higher control (tactical commander). The sequence of approach march, maneuver and battle run is taken straight through, immediately followed by a series of "synthetic" tests covering acquisition time and kill time. Weather and ground conditions are taken as they come above agreed minima.

Fatigued trials crew performance. After the "fresh crew" run the vehicle is replenished but not checked out; any specific defects reported are rectified. The crew is fed and rested to restore the men to their original physiological and psychological condition. They are then put through a synthetic fatigue and stress program (1), which is designed to be equivalent to around 60 hours of high intensity combat and culminates in reapplication of the physiological/psychological test battery. They then mount the vehicle and repeat the "fresh crew" test sequence over a different course. After this they are once again put through the test battery.

It is a nice point whether the fatigued trials crew would score above the fresh unit crew. My personal experience and the fact that trials crews tend to be older than unit crews indicate to me that this is likely but that the difference would be small, possibly not significant.

Fresh unit crew	Procedures as for trials crew
Fatigued unit crew	

On statistical design, I should like to see 6 test courses (with correction factors as necessary); having 2 sets of courses reduces giveaway wear and tear and allows time for natural recuperation and for restoration. It would be ideal to use 5 pairs of each standard of crew (20 in all) and 5 vehicles. I see no reason why initial trials should not be conducted with in-service vehicles to duck problems of availability of vehicles and/or trained crews. These results would be extremely interesting in themselves and provide useful pointers. Likewise debugging of the trials and statistical procedures would allow sample size to be reduced for new vehicles. In any event 2 crews of each standard should use the same vehicle as a check on vehicle-to-vehicle variations. It has to be worth including the crack trials crews both in

fairness to the designer and because the comparison between the trials and unit crews' scores would yield valuable data on methods and standards of training and on personnel selection. **But it is the unit crew scores which matter.** The percentage score of the fresh unit crew represents fightability; the difference between this and the tired unit crew's score represents the effect of habitability on fightability.

The purpose of **habitability trials** would be twofold - to identify specific design features which impair or promote habitability, and to establish the degree and nature of physiological and psychological deterioration which the synthetic fatigue and stress program of the fightability trials should produce. The medical test battery used would evidently need to be the same as in the fightability trial. Since training standards beyond a certain point are not too relevant here, the trials group proper should consist of average unit crews, which I guess would be likely to have a commander in the 25-30 age group and crewmen well under 25. However age is known to be a factor in stamina, and experience may be important in making the best of available habitability. So one would like to see these 3 small control groups -

one group of the youngest fully trained commanders and crewmen available

one group of crews of average unit ability but with commanders aged 30 to 35 and crewmen 25 to 30

one group of crack user trials crews, probably all noncoms, with an average age as high as possible in the 25 to 35 bracket.

Since they are required only to check on the existence or importance of unwanted variables, these control groups can be small.

Design of a habitability trial is really a matter for the appropriate medical experts, but a tentative suggestion might be to use these 3 phases -

unbuttoned living and moving (Chapter 3)

buttoned-up deployment and waiting under NBC threat (Chapter 4)

simulated intensive combat, with say a company-level combat team deployed on a battle run, live or simulated artillery and helicopter support and simulated enemy fire (Part 3).

These phases might be run 3 times each -

separately, with the crews starting each phase fresh and undergoing the test battery before and after

following straight through but with the test battery applied between phases as well as before and after the whole test

straight through with the test battery applied only before and after the whole test.

The reason for this suggestion is that waiting for and experiencing the test battery is itself an unwanted variable which may either have a restorative effect or augment total fatigue and stress.

I know of at least one place each in Canada, France, the FRG, Sweden, the UK and the USA where suitable terrain is available for such trials and the resources could be mustered. But these trials would not be cheap, so we need to explore the likely value of their results.

In an effort to get myself and the reader into the same ballpark, I will stick my neck out and guestimate the kind of result I at least would expect. This expectation is based on recall of HumRRO and APRE data (1), a 60 hour continuous exercise I set and carried out with the battalion combat team I commanded, and extensive observation and analysis of user and troop trials of various kinds. On fightability of current tanks (M60A3, Leopard 1, Chieftain) we might see something like this -

optimum	100
fresh trials crew	80
fatigued trials crew	55
fresh unit crew	50
fatigued unit crew	20

I know these figures are traumatic but I guess a deal of experienced opinion would not dispute them too vigorously.

As to habitability, again with seventies tanks, I would not expect a balanced pattern of unbuttoned living and moving to produce any psycho-physiological deterioration - maybe the reverse. Evidently an unduly high proportion of movement, specially at night, and extreme climatic conditions will result in progressive fatigue just like an auto rally does. My expectation is that in temperature conditions a 100 km road march to deployment positions followed by a 72 hour waiting period under NBC threat would equivalate to 48 hours of intensive fluid combat; and that either would represent the limit at which crews would remain reasonably battleworthy. A similar deployment move followed by a 96 hour buttoned-up waiting period or 60 hours of intensive fluid combat (equivalent to the "fatigued crews" of the suggested fightability trial) would leave crews only marginally battleworthy and susceptible to rapid further deterioration.

In the context of the demonstration of T72 to the French it became public knowledge that the Soviets only accept small men as tank crew (see page 2). Western designers work mostly to the 90th percentile of adult makes of combat age (2). This gives the Soviets an advantage of around 13 % in the armored volume of the crew compartment, probably worth as much as 15 % in battle weight (3). This accounts for much of the 20 to 25 % weight difference between Western tanks and their Soviet contemporaries, leaving only a balance of 5 to 7.5 % as an apparent tradeoff in fightability and/or habitability. On the kind of figures I pitched in above, this is a tradeoff the Warsaw Pact can very well afford. Since they can safely assume that NATO will never initiate chemical warfare and will hold back from tactical nuclear warfare initially, the Pact can do their living and moving unbuttoned. They have the resources to carry out formation reliefs after 48 hours or so of intense combat; and their concept of mechanized operations provides for just this, probably at divisional level (4).

So political virtue and financial constraints leave the West with little choice but to pay a price in weight for crew comfort, at least as long as the NATO powers subscribe to the main battle tank (MBT) concept. The question is,

though, whether the habitability and fightability they are getting are enough to ensure that they meet the opposition with at least reasonably fit crews. Unless my guestimates are extraordinarily wide of the mark, they are not enough. Any further increase in armored volume and thus in weight would be intolerable; and tnere are two reasons why this might not lead to the required improvement. Tanks are too complex for the available standard of crewman to fight; and the critical and unavoidable factor in crew deterioration is, I suspect, the psychological effect of long buttoned-up waiting periods.

There looks then to be a need for four radical changes. One, which I have insistently argued for, is abandoning the MBT concept in favor of a pair of dedicated weapon platforms - the tank destroyer (TD) and the fire support tank (FST). This move is likely to ease the training problem; to give the West a chance of getting the edge in mobility the defender needs; and to give the designer scope for novel and more efficient configurations. The second change, which we will assume throughout the book and discuss in Part 2, is the need to relieve the crews of the TD/FST pair and occupants of other key armored vehicles of servicing and maintenance duties, giving them in effect aircrew status in the field.

The third move begins with following the Swedish example of designing the vehicle as a whole from the viewpoints of crew duties and the duplicated and unique facilities required at each crew station. The exact nature of this rationalization depends both on the state of the art and on the operational and tactical concepts. The design of crew stations calls for the combined application of biotechnology and control engineering and - more important still - for knowledge in these disciplines to be compounded from fields ranging from aerospace to sophisticated comsumer durables.

The fourth change is the procedural one needed to make the resulting family of vehicles both effective and cost-effective. **It is an intensive, coordinated and above all a creative design effort**, based on the genuine state of the art and untrammeled by avoidable divisions of responsibility or by dogmatic user "requirements" prematurely spelled out in detail. With luck this could result in a design that was right first time. Over the two decades I was closely involved in it, British and United States armored vehicle development was a history of avoidable delays and waste of time and money, often resulting in a dangerous gap in capability. It took long enough to hammer user pipedreams fueled with technological optimism into the shape of viable user trials vehicles. Then time upon time these vehicles were found to be virtually unfightable even by expert crews. Sometimes it took what amounted to redevelopment to make them usable. Then funds ran short, politicians started asking awkward questions, and the project was further slowed down or even lost.

Nobody familiar with this history can doubt that fightability and habitability need to be treated as basic design parameters just like firepower, mobility and direct (armor) protection. Question is what priority to assign to them, specially since they are not strictly comparable with these three physical concepts. For this reason, and because I believe that limiting the key factors to three matches a model that can offer communication between user and designer, it may be more constructive to treat the human factors as considerations which qualify firepower and mobility. As I indicated above, we need to consider these major physical characteristics at 4 levels -

theoretical (calculated)

optimum practical (fresh trials crew)

achieved (fresh unit crew)

achieved and sustained (fatigued unit crew)

Bearing these levels in mind and accepting that they may differ very widely indeed, we can go on to look in more detail at the practical needs of armored vehicle crews.

Notes

1 In Britain and the United States alone, ample evidence exists on which to set up a physiological test battery and a fatigue and stress program. There is unclassified work by the American Human Resources Research Organization (HumRRO), the British Institutes of Naval and Aviation Medicine and Army Personnel Research Establishment (APRE), and work by civilian medical teams (in Britain under Medical Research Council auspices) such as the Applied Psychology Research Unit at Cambridge.

2 Sometimes the 50th percentile, thus making life very difficult for larger crewmen.

3 **Tank Warfare** Chapter 11. For once I find myself in disagreement with Professor Ogorkiewicz when he contends that the size of engine and engine compartment accounts for much of the difference in weight between Western and Soviet tanks with conventional armor distribution. For steel armor, a reduction of frontal aspect is around 12 times more important than a reduction of presented area elsewhere. Additionally most tank-developing countries reduce protection on the sides, deck and belly of the (rear) engine compartment below the nominal "thickness" of these aspects.

4 On information becoming openly available as this book was written and sent to press, the Soviets are moving towards a more deliberate doctrine which will make regular reliefs easier still.

CHAPTER 3

Living and Moving Unbuttoned

As I observed in *Tank Warfare*, we ask a great deal of the tanker. A glance ahead to the armored vehicles of the nineties with ultrahigh mobility and agility shows he will need judgment, skills and speed of reaction increasingly like those of a pilot. Yet at present we seem to expect him to produce these skills from an environment not too unlike that of a foxhole or a vintage combine harvester - and an environment from which he has no escape. He cannot carry the comforts of life around with him like a sailor, or step out of a clean, elegant machine into the luxury of a mess like an airman. During operations in developed countries, much of the ground force too lives in considerable comfort in requisitioned buildings for much of the time. But for one reason or another the armored vehicle crew has to live on its vehicle.

I already highlighted the stresses these men face in waiting periods under NBC threat and in combat, and we shall be exploring these in depth later on. The tanker's chance to relax and recharge his batteries comes when he is living and moving unbuttoned, out of contact and clear of NBC threat. It is self-evident that he must be given every chance to recuperate in these periods if he is to withstand buttoned-up waiting periods and to give of his best in battle. Many of the improvements discussed in this chapter will also play a part in buttoned-up habitability, and in fightability.

Although most of what follows applies *mutatis mutandis* to most configurations of armored vehicle weapon platform, conventional and novel alike, it will be helpful to establish common ground by postulating a layout as a basis for discussion. For Parts 1 and 2 of this book I shall use the configuration, derived from Swedish and United States technology, which I concluded in *Anti-tank* (Chapter 15) was the most likely common basis for the major armored vehicles of the nineties - the tank destroyer (TD), the fire support tank (FST), the infantry fighting vehicle (IFV) and its variant the command and support vehicle (CSV, fig 1). The front section contains the power train and some fuel tanks, which form part of an integrated compound armor array. This is separated by a bulkhead from the crew compartment with the driver on the left. A rotatable control console, in which the commander and his deputy (the gunner if you like) are seated side by side with duplicate facilities and driving override, occupies most of the width (1).

The TD could be a fixed-gun vehicle like S Tank (pl 2), with the hull in effect slaved to the console. The FST is an external gun tank of which the Swedish Marder/105 mm test vehicle (pl 3) is more or less representative (see

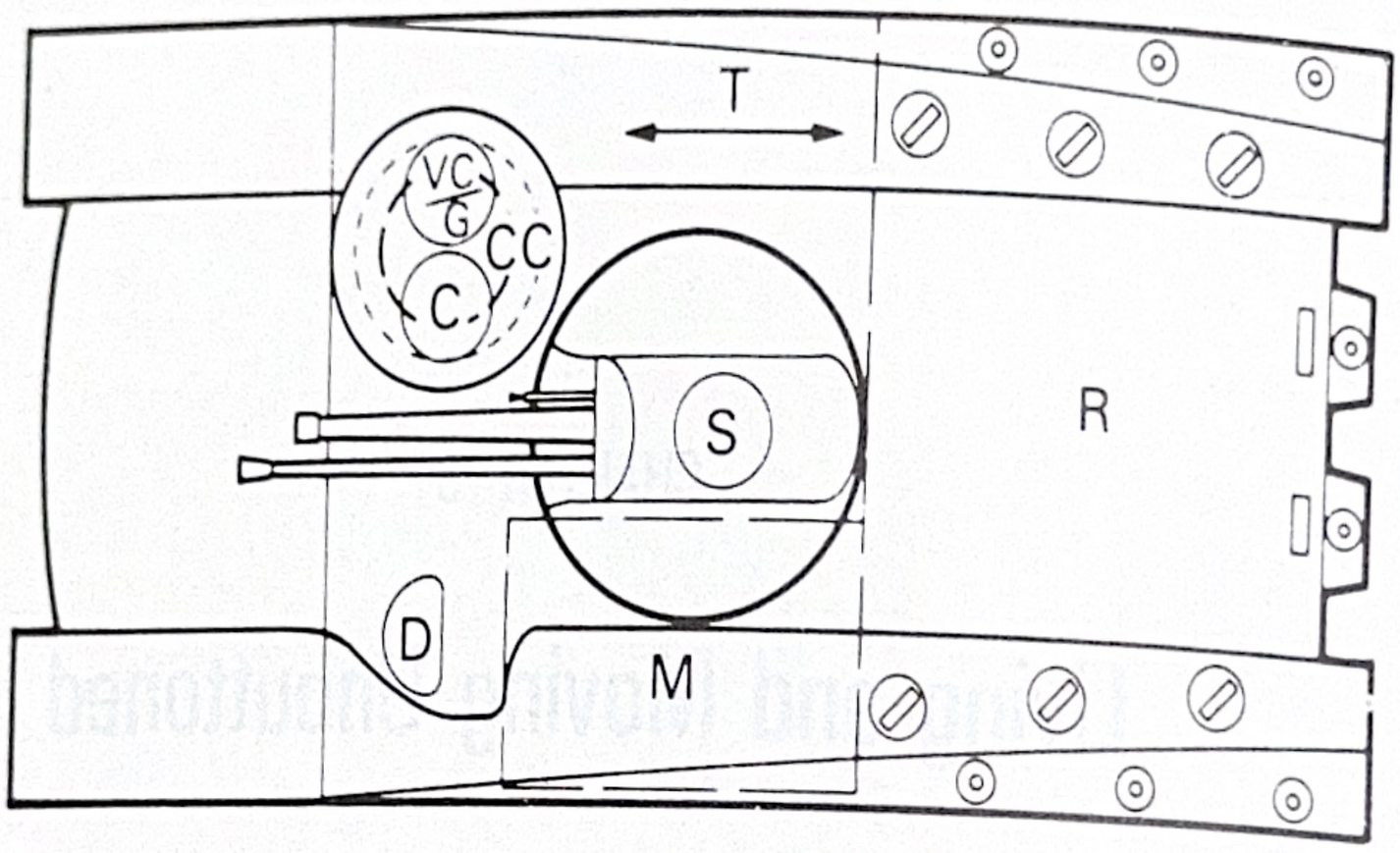

Figure 1. Vehicle configuration

This schematic shows the concept of the IFV/CSV member of the armored vehicle family postulated in my earlier book **Antitank**, which I have taken as a point of departure for this book.

Plate 2. S Tank

The pioneering S Tank, with its fixed gun configuration and the elements of an integrated compound armor system, was conceived as a "one-man tank with a crew of three." Additionally (with the exception of the driver's station in the British Chieftain) this was the first design to give serious attention to improving usable cross-country speed by sophisticated seating, along with safety harnesses and (anti-impact) protective clothing.

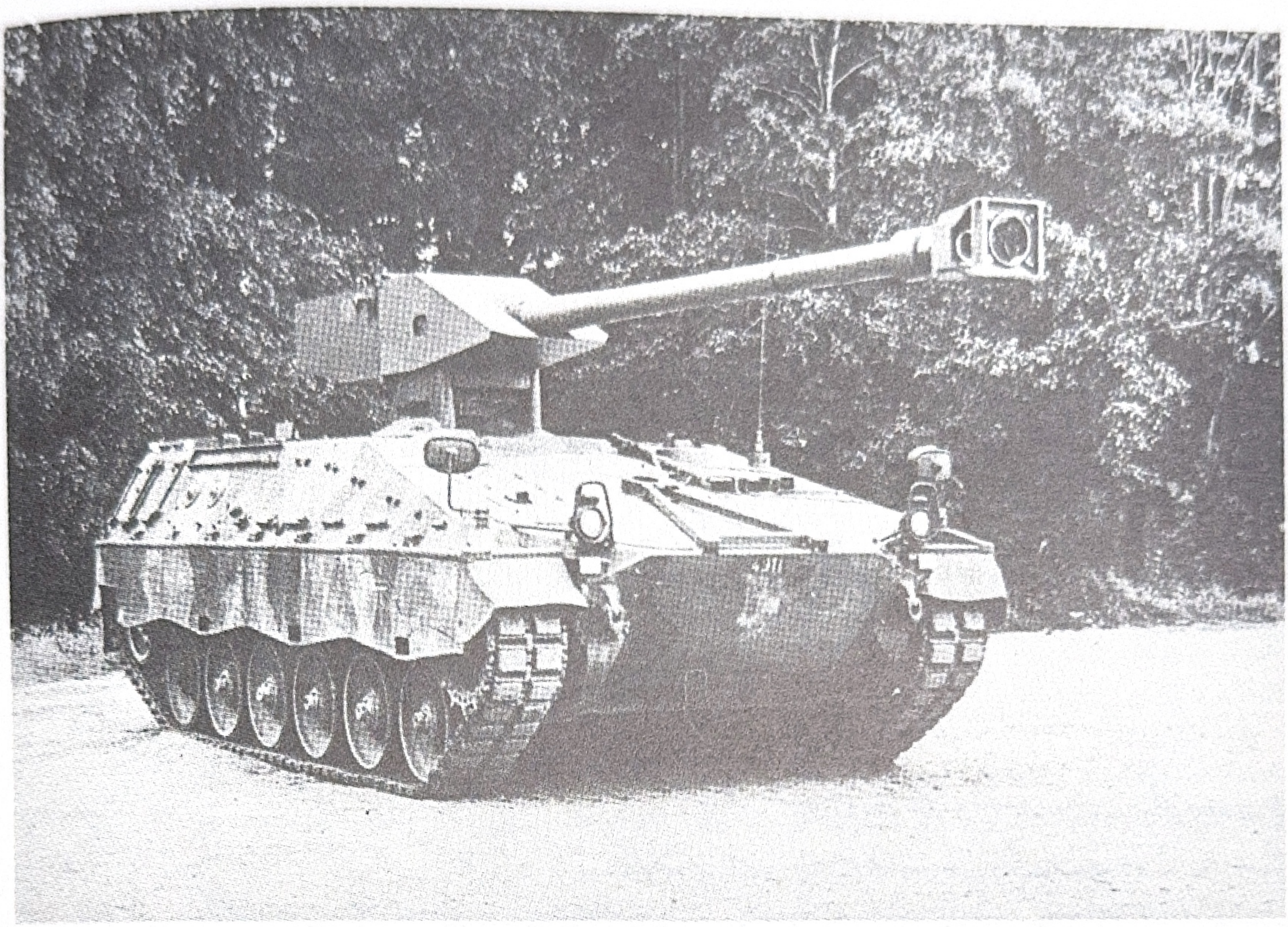

Plate 3. Swedish MARDER/105 mm Test Vehicle

The Swedish test vehicle, with the 105 mm/L51 gun externally mounted over a one-man turret on the German Marder hull, typifies the eighties approach to innovation. With an optical primary vision/sighting system, at least one man (here the gunner) must rotate with the gun. The commander would have a stabilized cupola right front, but his line of sight will be lower than the gunner's. So one feels the commander should be in the turret. But then there is no real role for the man in the cupola except help with surveillance.

caption). The IFV/CSV version shown in outline at fig 1 has a fire support weapon pod with 360° traverse and large angles of elevation and depression. This is slaved to the console and mounts a low-pressure 76 mm gun, a 20-30 mm cannon and a 7.62 mm machinegun. The crew compartment is lined with a layer of boronated polyethylene or such. This serves five purposes, three of which directly relate to crew comfort and survivability - attenuation of neutrons, absorption of spall and other fragments, thermal and sound insulation, and protection of the crew from minor injury (2).

We can link directly from this last point to the problems associated with movement (fig 2) - reducing fatigue, noise/vibration stress and the risk of injury (while at the same time increasing the vehicle's usable road and cross-country speeds). The excellent postwar British tank suit offered some physical protection; but the Swedes were the first to do anything much about this. Right from its inception S Tank bore the stamp of an aircraftlike approach. Determined to use the vehicle's performance to the full and faced with a sizable problem in the shape of violent pitching, the Swedes came up with a combined headset and crash helmet, safety harnesses and padded clothing. As well as its physical payoff, all this had a considerable morale effect - as it presumably does for ice hockey and American football players.

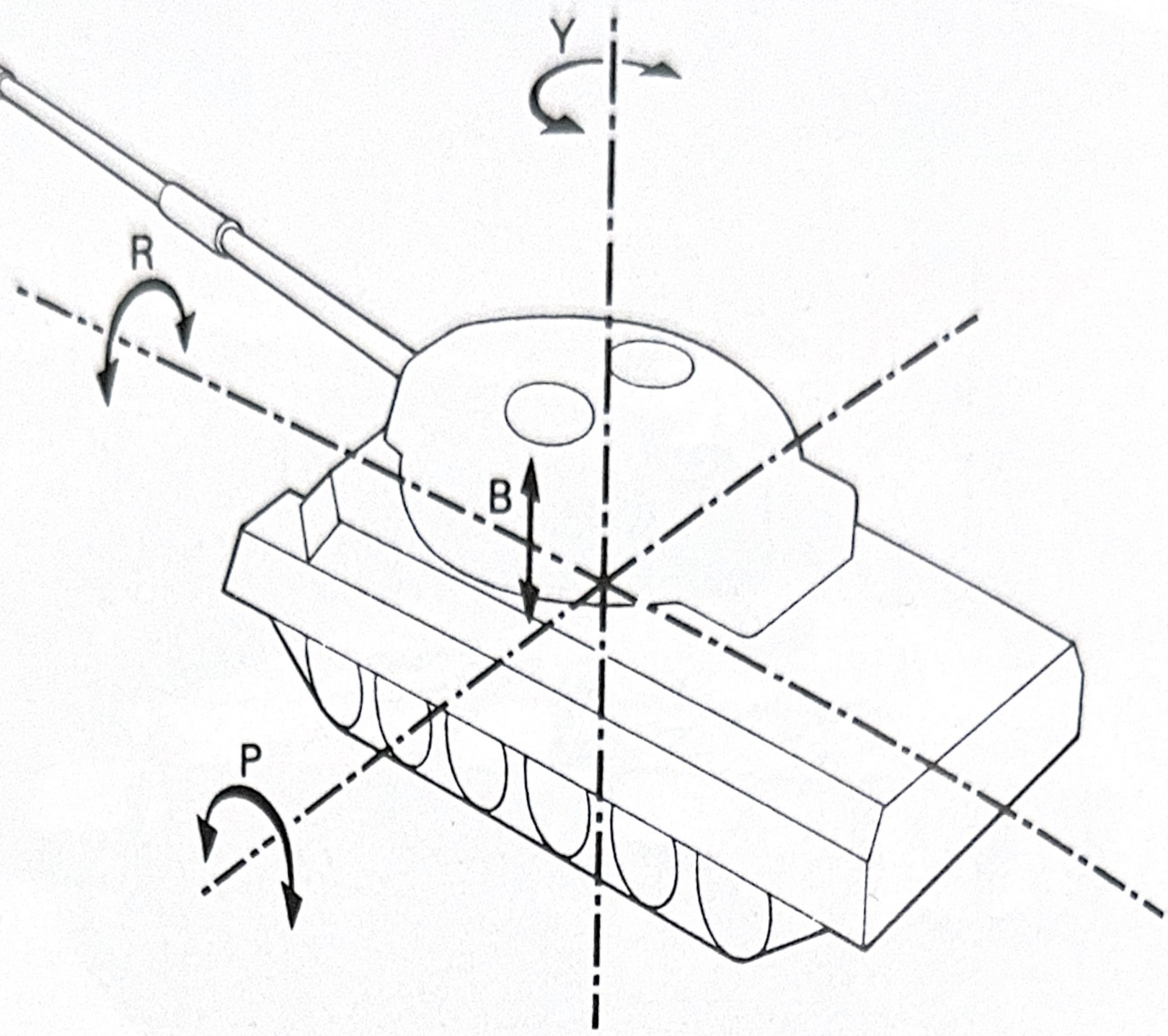

Figure 2. Components of motion

B = bounce, P = pitch, R = roll, Y = yaw

I for one do not go all the way with the Germans on two-phase stabilization - that is prestabilization of the hull aimed at making full stabilization of the mounting more manageable with the power available. But they, like the Americans and the Swedes, have now had considerable success in dealing with the basic motions of roll, pitch and yaw (fig 2). The fourth element, bounce, is of much higher frequency and lower amplitude; bounce and its secondary effects, notably resonances at low sonic frequencies, are a major factor in crew stress and fatigue. The initiation of these vibrations appears to be a fundamental characteristic of tracked running gears, probably associated with the pitch of the track links. But designers accept the need to protect electronic packs and optical instruments against this vibration by putting them on resilient mountings. They need to do the same for the crew!

This could surely be achieved in the shape of properly sprung, upholstered and contoured **seats** which shield the crew against the residues of all four effects. It may be tidy to discuss at this point other seating requirements too (fig 3). The seats should offer head-out and buttoned-up positions with equal comfort in both and a sufficient range of vertical adjustment to suit all heights. Additionally, in the down position they should, in conjunction if needs be with separate padded and adjustable rests, provide the head and arm support the crew members need to perform their main functions with ease and precision. Again in the down position of their vertical travel, these seats should offer a facility for reclining to the attitude medically recommended as appropriate for rest. This will evidently include head support; lowering of the back (combined if space restrictions require it with sliding forward of the seat proper); and the raising of a legrest to a suitable angle. It would be acceptable for the command console to be locked at 12 o'clock and the driver's foot controls (if any) to be covered when the seats are reclined. With a driving override facility on both console stations, any two members of the crew could recline and rest during movement.

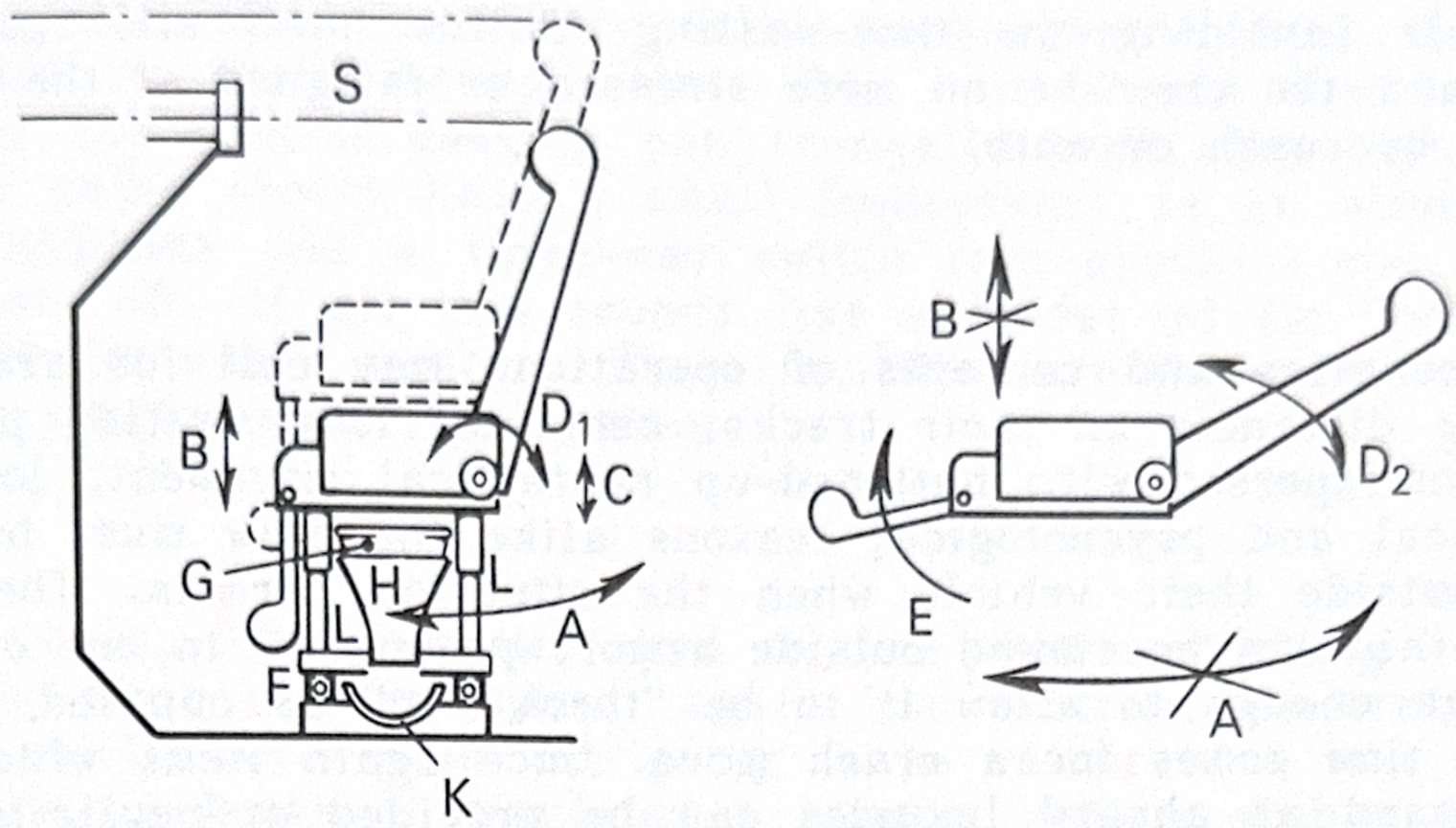

Figure 3. Seat and positions

"Rally-type" seat with lateral support round lumbar region, armrests and headrest/whiplash protector (with side supports).

A = 360° rotation, B = height change buttoned up/unbuttoned, C = height adjustment, D_1 = squab adjustment, D_2 = recline adjustment, E = conversion of footrest to legrest (with movements D_1 and D_2 on same control, D_2 and E available in 12 o'clock position only), F = supporting ring and race, G = washbasin with plug (lift-out seat cushion), H = lavatory pan/waste disposal (lift-out basin), K = lateral drainage channel (angled, with flush, outlet inboard of a roadwheel), L = air springs (motion B), S = line of sight.

The seat shown is designed to rotate within a fixed station. For a fully rotating station, the ring and race at F would be eliminated and the whole unit would rotate on a platform; in this case the internal and external faces of the periphery in the area of F would be available for a slipring arrangement. To wash the upper part of his body or change his clothes, the crewman kneels in front of the seat, facing it.

With a combined harness-free headset (working on an induction loop) and crash helmet, it would be pointless to carry ear muffs too. So it must be possible for crewmen to switch off their headsets when resting on the move. Here I want to start making the traditionalists leap up and down a bit - though I have several still better cards in this hand to play later! Future armored vehicles will have at least two, probably three net radio channels, and only one of these need be operative when moving out of contact. There is no reason that makes sense in terms of cost, bulk or power consumption why an auto-type radio/cassette player should not be fitted, or why the vehicle harness should not provide a changeover switch to feed the output from this into whichever channel of the induction loop is idle.

Vacuum bottles and jars, already standard equipment on armored vehicles for many years, should have stowage positions which allow the crew to eat and drink on the move. Fact is a vast amount of relevant know-how is available from auto rallying, small boat sailing and the biotechnology of long haul aircraft with small crews. The arrangement for urination and defecation needed for living under NBC threat (Chapter 4) should be suitable for use on the move too. Given that replenishment and minor scheduled maintenance is carried out at running replenishment points by maintenance personnel (see Part 2), there is no reason why moves should not be continuous over the complete range of

the vehicle (avoiding the time-wasting routine halts still practiced by many armies) and the crew be no more stressed or fatigued at the end of them than travelers by coach or auto.

Future scenarios and concepts of operations may call for armored vehicles to move long distances on their tracks; certainly long waiting periods under NBC threat, interspersed with buttoned-up nontactical movement, look inevitable. So for physical and psychological reasons alike the crew must be able to live in comfort outside their vehicle when the situation permits. The equipment they need for this can be stowed outside armor, preferably in one or more protective bins large enough to allow it to be "thrown in" as opposed to neatly packed when the time comes for a crash move. Once again items which many veterans would regard as absurd luxuries can be provided at negligible cost. Tankers with combat experience know that the crews which live best fight best. Sure, Duffy in the film *Battle of the Bulge* and Milo in *Catch 22* are caricatures; but like all memorable caricatures these contain more than a grain of truth and make a valid point. The constraint most worth considering is whether some of this living equipment can double as a survival pack. I am inclined to think it should not. A crash-out followed by unhorsing is a rather probable sequence of events and would leave the crew with their survival packs in chaos. Again, stowage space outside armor is not too much problem - specially if most of the tools and the like now carried are shed to maintenance vehicles and personnel - and we are talking of tens of dollars against a real unit cost slice of millions (3). All the equipment a crew could possibly want is commercially available in the mobile home/camper/tent market. Since it is not operationally essential and is easily replaced, it would probably be best to use commercial equipment, accept its limited life under field conditions and scale it accordingly.

The crew needs to be able to sleep on the engine deck (even if this is slightly sloped as in S Tank and Merkava), on the ground beside the vehicle, or a few meters from it. An armored vehicle camouflaged and left alone in a wood is far less likely to be spotted than a crew going through the motions of living, so that crew may need to retire into deeper cover where the vehicle cannot get. Inflatable equipment, "igloo"-type tents and air beds, are very attractive at first sight; but they take much too long to deflate and stow in a crash-out. The best solution is probably a simple frame tent with a fly, divided into an insect-proofed sleeping compartment and a fully enclosed well vented living compartment of which the front folds upwards and outwards like a porch. This is needed to conceal the signatures of cooking, eating and washing in the living compartment in daylight. An alternative frame or a set of adapters, along with sockets on the vehicle, is needed to allow this tent to be erected on the vehicle.

Following through my relative cost rationale, I suggest each member of the crew needs three sleeping bags. Two of these I shall deal with below and in Chapter 4. The one for sleeping on the deck of, or near the vehicle should have a waterproof bottom (so that it can be used without the tent), a foam rubber mattress, an insulating layer below the sleeper and a built-in pillow. Three models, varying in warmth and head protection, are probably needed - arctic (with a warm zippered hood), temperate (hoodless) and tropical (with an insect-proof hood).

The consequences of a fire are trebly serious because it may set fire to the vehicle and/or disclose the hide as well as injuring the crew. We shall discuss cooking in Chapter 7; briefly I favor liquid gas provided it is separately stowed in a vented bin outside armor. Electric lighting is safest.

Lamps should have alkaline secondary cells, rechargeable from the vehicle system via a unit in their stowage bin. This unit should also accept an extension lead for the electric cooking pan (normally used when buttoned up). The radio remote cable should have a small loudspeaker as an alternative to earphones, a microphone and a three-way switch (see above) - one net radio channel, broadcast, off. If all this sounds like a travel ad for "holidays by tank," that's just the way I want it. These facilities are the only form of R & R the tanker may see for a very long time.

Armored vehicle crews, like aircrew, need to feel that everything reasonable has been done for their survival. Also, again like aircrew, the trained crews future armored vehicles will need are going to be rather rare and expensive guys. In my previous books I stipulated a support vehicle within the (large composite) platoon, and one of this vehicle's roles is the recovery of unhorsed and/or injured crewmen. But this is not going to work every time. I once, after being unhorsed in anger, became isolated with my crew. I also explored this problem from time to time in trials and exercises. The answer is a lemon. For self-evident reasons, just about everything on the vehicle, along with most of the crew's clothing and equipment, is totally unsuitable for evasion and escape. So there is a need for **survival packs** in stowage that is protected but outside armor. These should be ready-packed rucksacks which, like parachutes, are never opened except for checking until required for their proper purpose.

Given high standards of fitness and plenty of evasion and escape training, I reckon even a fatigued or slightly injured crewman should be able to cope with a 20 kg pack. On the principle of double protection which most armies now follow, crews will presumably already be wearing NBC protective clothing. I would be against carrying a spare suit in the pack. Contrary to normal policy, a repair kit would be worthwhile here; and the rucksack should provide for the NBC suit to be rolled and strapped to the top of it.

We can break down the contents of this pack into fixed and climate-dependent groups. For the fixed items I would suggest these -

survival manual

"handkerchief-type" maps

simple luminous marching compass

torch (with hood)

smallest possible broadcast receiver (with earpiece)

spare batteries

first aid kit (including ethical drugs as appropriate)

foot powder

toilet paper

suicide pill (4)

amphetamine tablets or equivalent

1 l water bottle

CHAPTER 4

Waiting Periods Under NBC Threat

Enhanced radiation weapons may be another thing again, but normal tactical nuclear weapons (that is fission warheads with yields from say 1 to 10 kt) are less of a threat to troops warned, protected and correctly dispersed than the layman might suppose. The horrific damage radii we associate with these and larger weapons come mainly from target response - secondary effects such as fires and the collapse of buildings - and subsequent contamination from tropospheric fallout. Well over twenty years back, when I first studied the problems of training for, and morale in nuclear war, I concluded that the nuclear warfare environment was a sustainable one for ground forces in the field but questioned whether the chemical threat was not a battle-stopper. Given the nerve agents then known to be available and the kind of protection against them which was on offer at that time, it struck me that the conditions of an immediate chemical threat, let alone those following the employment of persistent nerve agents, would over a time prove psychologically and/or physically intolerable.

I know the Luftwaffe, the RAF and the USAF are fully aware of the problems of turning aircraft around even when contamination is limited to low concentration of low-grade persistent agents brought back on the aircraft. I know too that in this small but important field the British have gained a lead in personal protection, certainly over other Western nations and probably over the Soviets. Looking at published data about British protective clothing and Western collective protective systems, and at the standards of training achieved by the Soviet Army, I have to concede that, given proper support, the human organism can "pull something out of the bag" and lick even this problem.

In the heat of combat, with men's adrenalin flowing and casualties arising from gunshot wounds too, there now seems little doubt that well-trained troops, mounted and dismounted alike, will continue to fight effectively in a chemical environment - **provided that they go into battle fresh and fit.** I apologize to the professional reader if these paragraphs verge on the sensational. But I want to ram home the supreme importance of **maintaining the morale and physical fitness of armored vehicle crews during waiting periods under NBC threat.** Let us confine ourselves for the moment to temperate conditions, leaving the added problem of hot and cold climates over to the next chapter.

The fashionable NATO view, admittedly based on Soviet sources, is that Soviet tactical aviation and artillery are trained and authorized to treat chemical munitions as they do any other nonnuclear round - to use them from the

beginning when the situation demands them, without special authorization even from formation commanders. This is a view that suits the Warsaw Pact uncommonly well. I for one feel such political naivety to be quite uncharacteristic of the Soviets. But whether or not NATO has an offensive chemical capability, there is little doubt that the Pact will go chemical as soon as the going gets rough.

The policy of most armies now is that in combat crews must be **doubly protected** by wearing individual protection (possibly less the respirator) within the collectively protected environment in case the armored envelope is broached or they have to bale out; the implication of this requirement on design we will leave over to Chapter 18. During waiting and movement out of contact crews may rely on collective protection, because even if this breaks down they have time to don individual protection. The armored vehicle thus needs to offer a microenvironment within which a crew can remain for 96 hours or longer and still be fit to fight.

I can think of no parallel to the situation of the tank crew during a 3 to 4 day waiting period deployed in hides under NBC threat. Survivors on a liferaft have already suffered their main trauma and are concerned only with survival. Divers in a bathysphere or a minisubmarine are in a similar and considerably more dangerous environment. But their period submerged covers the accomplishment of their primary mission; they are occupied with their tasks; and they have good assurance of returning to safety and comfort after a time determined by their craft's endurance. By contrast tankers haven't started yet! The ordeal of waiting buttoned-up is simply the prelude to the more arduous and much more dangerous experience of battle. Crew and vehicle must emerge from this waiting period **fit to fight.**

This is a challenge not just for the crew themselves, but for doctors, biotechnologists, vehicle designers, recruiters and commanders alike. As far as I know Western users have hardly begun to scratch the surface of this problem. Once they get around to seeing it in perspective, they will I think need to say farewell to many preconceived ideas about armored vehicle design, and even to accept some tradeoff in theoretical fighting power. Easement of the "optimum achievable performance" we defined in Chapter 2 may result in higher levels of "fresh and fatigued unit crew performance," as well as in crews entering battle "fresh" rather than "fatigued." We might do worse than look first at the human aspects of this problem. We can then derive the requisite microenvironment from these, taking due account of the other principal requirements.

For starters, the problem of **modesty** has to come out into the open. Since I have seen little work on the relevant aspects of modesty, I am basing what I say on a broad spectrum of relevant personal experience - not just tanking, but life as a prisoner of war and offshore sailing with both male and mixed crews. Modesty between men seems generally to be more pronounced than it is between women. In modesty between the sexes too, men seem at least as sensitive as women, possibly more so. My experience (evidently for the most part in and associated with the armed forces) is that modesty varies inversely with social class and/or level of education. Certainly the type of enlisted man who makes a good tanker is apt to be extremely modest. This observation, though, may be distorted by two factors.

One is that no relationship, even marriage, can be sustained without reticences. In an armored vehicle or a small yacht, manned by a group whose members have not necessarily chosen each other and are forced to spend long periods cheek by jowl, relationships probably demand an exceptionally high level of reticences, including the physical reticences which add up to modesty.

The second factor is that officers are apt to be low on modesty and insensitive to their men's attitude in this respect. The reasons for this are not hard to see. Most British officers, and some in other armies, spend up to ten years in a boarding school before they join West Point, Sandhurst, St Cyr, the Moscow Officers' School or wherever to "have the corners knocked off them." This is a euphemism for dehumanization; and to this extent many young officers who are in direct contact with enlisted men in armored vehicles are dehumanized. It takes many years, often including a university course and/or a successful marriage, for them to revert to normal in this respect.

By contrast the keynote to a solution of the waiting period lies, I am convinced, in the **avoidance of dehumanization** - in fact in the buildup and conservation of individuality. Nothing I have seen inside the armed forces or elsewhere has shaken the conviction I went on record with over 20 years back - that arduous training (like evasion and escape exercises) and the martial arts (1) fit a man far better for modern war, both physically and psychologically, than the drill square, team games and boxing. Sure, soldiering is about teamwork; but nowadays it needs to be about teamwork between small groups of individuals with a high respect for themselves and each other, not between dehumanized automata.

So modesty is a prime requirement, comprehending minimization of physical exposure, privacy in urination and defecation, suppression or localization of the odors of these processes (2) and swift, private disposal of the products. Strangely enough, I have noted that even acts involving no exposure of the buttocks or genitals, which are as a rule performed communally without a second thought, may become subjects of reticence during protracted confinement at close quarters. **Washing arrangements** should if possible take some account of this, though at a far lower priority than the main factors in modesty. (Lest the reader think I am indulging in idle fantasy, I will shortly offer a technical solution suitable for some configurations of armored vehicle.)

The waiting period and the subsequent period of intensive combat and/or movement may well together last at least a week. So washing is not enough to ensure that the soft parts remain free of skin conditions likely to impair at least the ability to evade and escape if not the execution of crew duties. We can be sure that future vehicles will not have a large "utility" area accessible to all in turn like the loader's station in Centurion (fig 4). Changing clothes is going to be difficult; anyway changes of normal clothing take up valuable internal stowage space; dirty clothes smell and cannot be washed.

Once again I have to risk being laughed at, but there looks to be a case for disposable "under-underclothes" which can be changed with minimal displacement of the outer garments. These would absorb perspiration from the soft parts and certain other areas, along with normal minor discharges from the rectum or penis; they could be changed every time a man washed, and disposed of with other waste matter. Possibly a set could consist of a scarf, a pair of armpit pads, a "G string" and inner socks. All these points, trivial in themselves, need thought and thorough trial to make them effective and acceptable and to minimize cost and bulk.

Boredom will evidently be a major and psychologically dangerous problem. Back in the previous chapter I proposed including an auto-type radio/cassette player to help relaxation during moves. In a period of waiting buttoned-up under radio silence, this broadcast radio could also offer a means of passing unclassified but nonetheless important messages. By the same token a tuner/converter unit could put color television onto the monitor/display unit

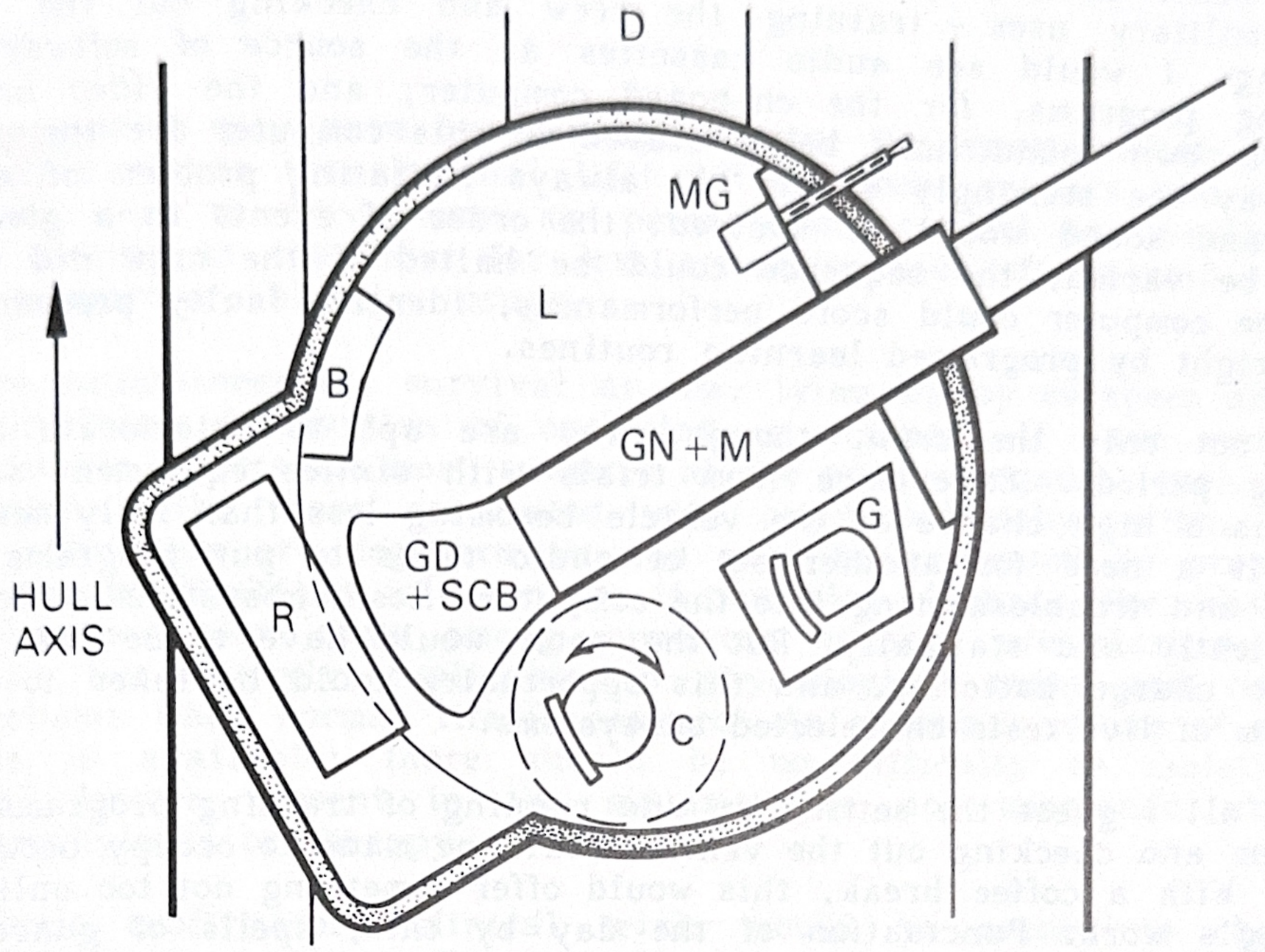

Figure 4. Conventional turret (Centurion) - schematic plan view

This is based on Centurion but applies to many tanks. B = sliding bins (2 x 2 rds 105 mm), C = commander (rotating seat), D = driver, G = gunner (seat back removable), GD + SCB = guard and spent case bin, GN + M = gun and mounting, L = loader, MG = machinegun etc, R = radio etc.

Here the turret is at around 2 o'clock; the gun is envisioned as fully elevated, i.e. with part to rear of trunnions depressed. Loader's space is about 150 % of commander's swept volume (broken circle) and 200 % that of gunner. With back of driver's seat collapsed, driver can enter turret. Commander and gunner can climb over gun, so all crew can change places or take turns in loader's space. Rest positions are : C - lies on gun (or as G), G - lies in C + G positions with gunner's seat back removed and a plank (or as C), L - fetal position in turret basket (or as D), D - lies on seat with back collapsed and stowage etc under legs (or as L).

which will inevitably form a part of each crew station; here coded messages using one of the accepted commercial techniques (but with a changing key) could be superimposed.

I appreciate that the traditionalists will by now be at the hover on small purple clouds with balloons like /Paper undies!" or "Television in a tank!" But within an objective rationale of relative costs, a television facility makes sense in terms of morale alone. In fact, though, there are very good military reasons for it. **Training** would at once alleviate boredom and keep skills and reactions topped up during these waiting periods; but it must take place without giving any form of signature outside the vehicle. So a simulator would be needed, and the best form of simulator would be a videotape. Once there is a videotape deck, it can fairly easily be persuaded to play educational, documentary and feature tapes. So now we have most all home comforts, and thus a far more normal environment.

There is one further application of these audio and video cassette players which bears on the wellbeing of the crew, but let us stay for a moment with their military uses - training the crew and checking out the vehicle. For training, I would see audio cassettes as the source of software, including training programs, for the on-board computer; and the video unit (complete with its own soundtrack) being slaved to this computer for the playback. In this way the seemingly simple but always irritating problem of synchronizing sight and sound would be avoided; the order of events in a given videotape could be varied; the sequence could be halted if the crew did not respond; and the computer could score performances, identify faulty procedures and put these right by programed learning routines.

It is not only the crew, though, who are apt to deteriorate during these waiting periods. Experience from trials with sixties equipment suggests that there is a high chance of the vehicle becoming less than fully serviceable. So there is a need for another set of audio tapes to put programs for routine checks and troubleshooting into the computer. Most subsystems could be checked out silently and statically. But the motor would have to be run from time to time to charge batteries, and this opportunity could be taken to carry out a program of live tests on selected subsystems.

All in all I guess the setting up and running of training programs, debriefing on them and checking out the vehicle could be made to occupy between 3 and 4 hours. With a coffee break, this would offer something not too unlike a normal morning's work. Punctuation of the day by this, spells of guard duty when needed and set times for special broadcasts would be of enormous psychological and physiological value in **creating a routine** familiar enough to support the soldier's conditioned biological clock.

I am convinced that careful development on the lines so far indicated would, without significant cost penalty or design tradeoffs, turn a situation that nobody much cares to face up to into one that is easily manageable within the normal service framework. The next problem to be tackled is the crew's **physical fitness.** This must be maintained both to avoid impairment of morale during the waiting period and to leave them in every way fit to fight at the end of it. Isometric exercise routines should in any event be taught to all soldiers and airmen as part of their evasion and escape training, so that they can lie up and remain able to move instantly, far and fast.

Some folks, though, do find this type of exercises hard to master and appallingly boring; others have physical peculiarities which may make certain standard exercises difficult and even harmful for them. So some kind of encouragement or backup is needed; and individually designed programs are desirable. Given the facilities I already (I hope!) justified, I would like to go the whole hog here too. During his initial training or in post, each crewman should have a videotape with an individualized program of, say, 30 progressive sessions of isometric exercises (10 days, three times daily). If he entered the waiting period fully fit, he would start at maybe Day 5; but it would be useful to have some less demanding sequences as a fallback in case of mobilization straight off leave, illness and post-combat recuperation during lulls.

I would further see these tapes as in every sense individualized to gain the greatest possible morale effect from them. Having studied the subject's idiosyncrasies and devised a program, if needs be with medical or paramedical support, an attractive and supportive physical education instructress would make the tape, using the subject's known difficulties to interact with him by

correction and repetition. As A W Gilbert (3) put it: "When a man's afraid, the sight of a maid is a wonderful thing to see."

That last suggestion may have been enough to give the traditionalists hovering on their purple clouds translational lift! But for those readers who are still around I now want to drive home my points about comfort and psychological support by looking at the other far less attractive side of the coin - **chemotherapeutic support** or, bluntly, drugs.

High-altitude mountaineering, survival at sea, lying up by escapees and other situations involving deprivation of one kind or another all have known and fairly predictable effects on most subjects at the purely organic level. Some of these conditions, like those associated with protracted dehydration, lack of oxygen, or starvation are degenerative and must be prevented by prophylaxis (and of course by limitation of exposure if possible). Others, like constipation over weeks rather than days among survivors at sea, are alarming to the unitiated (4) but entirely explicable in physiological terms and harmless; normality returns when normal life is resumed. An enormous volume of evidence on all this is available; there should be no difficulty in isolating the physiological factors present in the situation we are concerned with and providing prophylaxis or therapy.

Evidently some confirmatory clinical trials would be needed to check for interactions or compounding effects within the total situation and for any indications specific to a given factor. Studies of this kind would also provide an opportunity to prepare briefing material. Given good briefing, an appropriately controlled diet (Chapter 7) and the necessary medicaments, this aspect should present no great problem. Once again tapes could be used to reinforce advance briefing, to provide encouragement and to give advice on the treatment of fortuitous conditions (like colds, flu, gastroenteritis, skin conditions or minor injuries) under circumstances of buttoned-up waiting. All this is straightforward and has few wider implications.

The use of drugs for **psychological support** is another thing again, specially when their abuse is widespread not only in societies as a whole but in most armed forces and other large isolated groups. The effect even of mild and well-established drugs in small doses on subjects of similar consitituion (in terms of sex, age, body weight and fitness) cannot be predicted with any precision. Additionally commanders of forces drawn from advanced societies have always been chary of using drugs because the unpredictability of their effect is compounded by the far greater uncertainties of war. For instance there is a good case for the use of amphetamines to extend endurance both in commando-type raids and in intensive phases of normal operations. The problem comes when the bought time has to be paid for. If the climax of a raid has to be postponed 24 or 48 hours at the last moment, or the clinching thrust of an operation goes awry, the commander is left with troops far less capable than they would otherwise have been.

In *Tank Warfare*, writing in terms of an efficient turreted tank, the state of the biotechnological art as it then appeared, and the scope of the chip still none too clear, I reckoned that some kind of chemotherapeutic support program, at least to the tune of mild nonbarbiturate sleeping pills and quite possibly including antidepressants, was essential despite the evident hazards. Now I am not so sure. We shall see shortly that the layout I am basing this book on (page 24), derived from the principle of optimizing crew stations and slaving armaments to them, goes a long way towards alleviating the physical difficulties of confinement. Fully exploited in the "all-singing, all-dancing"

ways I have described above, the electronics which will for the most part be on board anyways can, I guess, lick the severe psychological problem too.

Success in this respect depends on putting all the pieces of activity and relaxation together into a **routine** compatible with the human biological clock and as like as possible to a normal day's soldiering. Given that guard duty can be spread over 12-15 men (5) and that the optimum period for watching sensor displays without the possibility of physical movement is one hour (with $1\frac{1}{2}$ hours as a maximum), guard duties can be used to break the routine without disrupting it. With suitable rations and facilities (Chapter 7), the preparation, consumption and cleaning up of each meal can be spread over an hour or more. Likewise washing and shaving in the confined space will take each man around half an hour; men can do this in turn while the others relax or go through their individualized routines of isometric exercises. Checking out the vehicle and silent exercising of subsystems can occupy an hour, and engine running around 15 minutes (normally in darkness). Training could I think be stretched to 3 hours per day, say evenly divided between crew drills, aircraft/vehicle recognition and background. So one arrives at a routine something like Table 1; if some of the timings seem generous, I would stress that the name of the game is killing time.

I now want to turn to the material facilities other than electronics needed to make buttoned-up existence tolerable. The first requirement is to develop the **collective NBC protection system** in two ways - to hold the temperature, humidity and carbon dioxide content of the crew compartment within tolerable limits; and to provide enough redundancy (in other words reliability) to make the chance of the crew having to don individual protection extremely small.

The primary need for comfort and wellbeing under confined and most other conditions is an ample supply of **water.** The vehicle's under-armor supplies of water and fuel must be conserved during the waiting period; if either or both form part of an integrated protective system, it is doubly important for the vehicle to go into battle with full tanks. One must assume that vehicles will be topped up at a running replenishment point as they enter the deployment waiting area. Given this, a jettisonable **deployment roof pack** of water and fuel, collapsible and contoured to fit the upper front and unused roof area, would improve protection against neutrons and thermal insulation. 600 l of water and 200 l of DERV would be ample for 7 days under buttoned-up waiting conditions in a temperate climate. In an expendable pack this payload would represent an overload well within the mud allowance for an MLC40 vehicle and thus acceptable for movement to the deployment area. A trailer used only for deployment is another possibility (see page 45).

The next key point is the disposal of liquid and solid waste, specially urine, feces and toilet paper. Other solid waste can be disposed of through a hatch low down on the side, preferably behind a roadwheel, provided that it is first placed in opaque bags with a dark mat surface to prevent any risk of sun glint. Evidently if the vehicle occupies its hide before an NBC alert is declared, the crew should dig or doze out a waste trench and drive the vehicle over it.

For excreta the options of empty food cans or a communal chamber pot, and plastic bags do not march well with the environment I propose. Plastic bags are awkward to use and a good deal of odor is released by the time the toilet paper is in the bag and it gets sealed. In a turreted tank with conventional (i.e. minimal) seating I can see no alternative. But in a single-level layout, specially with the crew in line, a much pleasanter solution lies to hand.

TABLE 1. Possible routine for buttoned-up waiting periods

NOTES 1 Guard duties superimposed, say 2 hrs/man/day.

2 Entertainment radio/cassette/TV available to each crew station at all times.

Time	Event	Remarks
06.45	Reveille, brew coffee	06.50-07.00 for broadcast of special audio messages
07.00-08.30	Wash, shave, isometric exercises Routine 1	In turn
08.30-09.30	Breakfast	
09.30-10.30	Vehicle checkout, silent exercise of subsystems	
10.30-11.00	Coffee	
11.00-12.00	Training session 1	
12.00-12.45	Isometric exercises Routine 2	15 minutes each, in turn, on individualized routine
12.45-14.15	Midday meal	
14.15-15.00	Rest	
15.00-16.00	Training session 2	
16.00-16.30	Coffee	
16.30-17.30	Training session 3	
17.30-17.45	Reserved for special broadcast video messages	Engines to be run in dark, staggered over co-located vehicles
17.45-18.30	Isometric exercises Routine 3	
18.30-19.00	Run engine, exercise subsystems, repeat key checkouts	
19.00-20.30	Evening meal	
20.30-22.30	Feature film	Broadcast or videotape
22.30	Assume night routine	

It's strange how often one's work in entirely unrelated fields ties up. Shortly before starting to write this book, I happened to be translating a(fairly) learned paper on Roman baths. From this I discovered the origin of the water closet. Faced with the problem of disposing of the excreta of numerous bathers,

an engineer simply arranged for the (open) outlet channel of the baths to run almost horizontally under a long bench with a row of holes in it. (Modesty, incidentally, was of little concern to the Romans, so the cost and space of partitions was spared.)

Various devices on the commercial market combine a seat, washbasin and toilet (6). With the type of seat envisioned (fig 3, page 23) it would be very easy to arrange for the center of the seat in the "down upright" position to be over a funnel leading to a pipe or channel and thence to a protected aperture in the lower side (again behind a roadwheel). With an ample water supply it would be easy to flush away feces, paper and semisolid food waste. If needs be a disinfectant and deodorant chemical could be injected into the flushing water. The arrangement on the seat itself would be even simpler. Lifting out the cushion discloses a circular washbasin; lifting out the washbasin discloses the seat and the funnel. This is a very good example of the way existing technology (ancient and modern!) can be applied to the habitability of armored vehicles.

Victualing and cooking facilities apart, this leaves only sleeping arrangements to be considered. In a single-level layout, specially a side-by-side one, the various requirements for privacy can be met by small curtains (like shower curtains) hung by hooks and rings from the crew-compartment ceiling. Even where the temperature maintained inside the vehicle and the clothes worn make keeping warm no problem, the psychological advantage of marking off night and day would, I think, favor the provision of lightweight sleeping bags.

Readers may see this chapter as the ravings of a tanker in his dotage or as deliberate exaggeration aimed at driving home a point. It is neither. I don't reckon a single country within NATO has faced up sensibly to any aspect of the problems of persistent chemical and/or radiological contamination. The Soviets have militarily; Sweden and Switzerland have, at least on the side of protection of the population. Every officer and senior noncom in NATO must know the opening pages of the scenario. Unless the problem of waiting deployed under NBC threat is confronted and solved, NATO is just not going to have many soldiers physically and psychologically fit to fight when the moment comes.

Notes

1 In the sense that these make use of the opponent's strength and exertions.

2 Long known to be a major factor in morale in hospital wards.

3 The librettist of the Gilbert and Sullivan operettas, all-time favorites in Britain and, until very recently, dead flops outside it.

4 To the point where countermeasures which are irrelevant or actually harmful may be applied.

5 Assuming a fail-safe intervehicle alarm system and varied groupings of the composite platoons suggested in my earlier books.

6 I know of at least one marine toilet for very small cruisers which has this arrangement, and there are similar ones (usually over a chemical toilet) for campers (British "motor caravans") and the like.

CHAPTER 5

Extreme Climates

A variety of nineties scenarios depict mechanized operations in extreme climates. While both the climatic conditions themselves and other factors make the chemical threat less probable than in the NATO center and the tactical nuclear one more so, the NBC threat as a whole remains. By contrast I do not see protracted waiting periods of the kind discussed in the last chapter, if only because much of the terrain suitable for armored vehicles lacks the requisite cover for hides. Extension of the Swedish work on articulated armored vehicles to train weights around MLC40 or more (pl 5) would however reduce nominal ground pressure and width to a point which would open whole new areas to mechanized operations (1). It is still too early to say, though, whether articulated vehicles will prove attractive to forces which are not primarily designed to operate on surfaces of very low bearing pressure and/or defile-ridden terrain. I believe we can confine ourselves to a range of +33°C and 110 % relative humidity (or a combination of rather higher ambient temperature but lower humidity) down to - 30°C with no direct exposure of the human body to wind chill.

In discussing extremes however we need to hoist in one message which does not seem to be too widely understood. Whatever forms future direct protection may take, an armored vehicle is going to remain basically a large chunk of metal - an object with a high thermal capacity. Its surface and interior temperatures will tend to lag behind changes in ambient temperature but to reach extremes beyond ambient temperature under certain conditions, notably sunlight and wind chill. Vehicles are often brought to and held at a steady state in hot and cold test chambers, but I am not too sure how often this happens within the normal 24-hour cycle of ambient conditions. Another key technical point is that many of the vehicle's subsystems are even more temperature-sensitive than the crew. Quite apart from batteries, propellant charges and some electronic and optronic systems suffer from this characteristic.

Since considerable amounts of power (of the order of kilowatts) are involved in both air conditioning and heating, we need to examine both combat and standby conditions. Evidently though the cold combat situation will not be critical if reasonable use is made of engine heat. Quite apart from representing an extreme in absolute terms, the hot/humid combat situation under NBC threat gives rise to the need to help the crew, who will be wearing full personal protection when in combat (page 29), to get rid of body heat.

Plate 4. The Swedish articulated tank destroyer UDES XX 19.

This photograph of a model of the first member of the proposed Swedish family of articulated armored vehicles to go into development - a tank destroyer with a train weight of around 24 t and limited usable traverse for its (German) 120 mm smoothbore gun - surmounting an obstacle. "Double articulation," that is control of the vertical as well as the horizontal angle between the two parts, offers many advantages but may present problems for the driver unless/until he has optronic rear vision. In this version, now in prototype, the commander's "pop-up" station is enclosed in a cylindrical sheath and can be elevated to give him observation at/above gun level.

Experience suggests that well trained and disciplined Caucasian crews, once fully acclimatized, can just about cope with extreme hot/humid conditions if they keep their hatches open and are allowed flexibility over dress (2). Heat exhaustion has to be constantly watched for; but its incidence is low (of the order of fractional percentages per day) and the onset of symptoms is gradual (3). Given knowledgeable noncoms, a buddy system and a bit of luck, fatalities are rare. My subjective recall suggests that the conditions are rather more marginal than hot chamber tests indicate. This is probably because in real life neither monitoring nor personal discipline is perfect. What seems beyond dispute, though, is that men wearing full personal NBC protection in buttoned-up vehicles will be well over the top.

In these terms the reliability of the air-conditioning system is as critical to combat effectiveness and indeed to survival as the collective NBC protection system downstream of it. It may be necessary to ease inhalation through respirators by boosting the collective system with individual blowers and hoses and/or to remove body heat and moisture by circulating air within protective

clothing. But I do not think we can contemplate an independent backup system providing air-conditioning and filtration in addition to the primary system and individual protection. Anyways, once the air-conditioning is firmly tied in with the NBC collective protection system, it may be preferable to leave the crew unencumbered and hold the crew compartment within acceptably narrow limits. I would put these at a maximum of 21°C and 70 % relative humidity and a minimum of 13°C; this should cater both for the crew and for the temperature-sensitive subsystems.

This adds up to quite a task, though. It is tempting to provide the flow of conditioned and filtered air only to specific areas. But when one examines the needs of the primary armored vehicle family as a whole, there is an evident payoff in going for a standard system capable of coping with the whole armored envelope behind the engine bulkhead (see fig 1, page 20) at a level which obviates the need for individual boosters (4). The problem differs too widely from that of a turreted tank on the one hand or an armored personnel carrier on the other to extrapolate from these; additionally maintenance of full atmospheric pressure in the output from the air-conditioner to the NBC system proper has to be ensured. But by a process which I would not even venture to call guestimating I arrived at a maximum power requirement for air conditioning of around 3 kw.

For a vehicle with a typical battery capacity of 200 Ah this, superimposed on the "NBC standby load", is going to mean running the engine around once an hour - presumably idling for a short time only if it has a high capacity alternator. The best modern practice is opposed to building in an auxiliary engine and generator; and one can assume that the vehicle electrics are designed to give an acceptable silent period under NBC threat in temperate climates. So the only alternative to frequent running of the engine would be the provision of a small external motor-generator.

The audio signature of a unit like this is likely to be as adverse in tactical terms as that of the main engine idling. The need for air conditioning in the standby state arises mainly under NBC threat. The air-conditioning load falls off markedly at night in most areas which have suitable terrain. Automatic starting and stopping is no more difficult to arrange for the main engine than it is for an auxiliary. And since the main engine is virtually certain to be of the compression ignition (diesel) type, it will run economically at idle. Since electricity is the only form of energy that will do here, the answer looks to be to rely on the main engine and the normal power electrics (5).

Cold conditions pose quite a different requirement, independent of NBC threat and related only to the standby state. To keep the armored envelope aft of the bulkhead warm during movement and combat, some kind of heat exchange with the engine compartment will presumably be arranged. By contrast the heat given off by the modern forms of the subsystems in use during standby is slight. The requirement is for up to 5 kw of straight thermal energy. This can best be provided by a pulse-jet diesel heater of the Swingfire type (6). This heater should be mounted externally but operable from within the vehicle.

To obviate the need for a separate system to circulate warm air (whether from the engine or the heater), the NBC collective protection system should be used. There is no problem about bypassing the filters and providing a much reduced fan speed. This would also allow the air-conditioning system to be used in the absence of an NBC threat should conditions make this desirable, and would provide ventilation in temperate climates.

The two problems that remain are location of the air conditioner or heater and ducting of the air from it to the NBC system intake. Future armored vehicles are unlikely to have a convenient turret bustle, basket or bin; and either the hot or the cold add-on pack could be large enough to spoil a low and compact silhouette. I reckon the rearmost stowage bin on the same side as the NBC system air intake will have to be used to accommodate the hot or cold unit. In this event flat ducting could be led along a fixed or otherwise unused part of the roof area to fit over the NBC system intake grille. This ducting and the connections at its extremities would need to be thermally shielded. A panel at the back of the bin to be used could carry the electrical and fuel connections. To round the picture off these should include a low-power heating element to stop the water in the "deployment tank" or trailer (pages 34 and 45) from freezing.

I have to admit to being very far from happy about the notion of fighting armored vehicles in extreme heat while wearing full protective clothing. Technically, though, both this problem and that of winter or subarctic conditions look to be soluble by the use of add-on packs linked to the NBC collective protection system.

Notes

1 Likewise the possibility of "task configuration" of rigid or articulated vehicles of modular design (see Chapter 15 and Bibliography, **Armor Magazine**) offers a step advance in the strategic mobility of a powerful and flexible mechanized intervention force.

2 I believe Aden and the South Yemen littoral represent the worst conditions prevailing in terrain where current armored vehicles can operate. Despite desert conditions of high temperature, intense sunlight and no shade, the relative humidity is extremely high (often supersaturated). Additionally the atmosphere is laden with corrosive salts, but these affect hardware more than men.

3 Extreme physical exertion can produce sudden collapse from heat exhaustion ("heat-stroke"), often leading to death or irreversible damage before adequate treatment can be applied. But in situations of limited and even intense exertion, men can and must be trained to recognize the early symptoms in time to prevent the onset of the acute stage.

4 In a modular vehicle family there are arguments for separate systems in crew and rear compartments, but the amount of **total** air flow remains about the same.

5 It is becoming increasingly necessary to think in terms of separate "power circuits" and "control/electronic circuits", as in a factory or such.

6 Not to be confused with the British ATGMS! This is a German design, originally known as "Schwingfeuer".

CHAPTER 6

The Infantry Fighting Vehicle

Ever since the tactical nuclear heyday of the fifties, a number of leading armies seem to have labored under the illusion that anything up to a dozen men could live, eat and undergo long buttoned-up waiting periods in a small tin can (like BTR50PK, FV432 or M113) in just the same way as the four-man crew of the relatively spacious tanks of those decades. This capability was frequently "demonstrated" and periodically trialed in a tactfully limited kind of way. But I know of no trials - even in the US Army's Combat Development Command program - which put an APC-borne squad through a full cycle of "deployment/waiting under NBC threat/move to battle positions" and checked out the men's fitness to dismount and fight at the end of it. Like so much that concerns mechanized infantry, this is in the same doublethink league as supposing the same troops can be in two different roles and places at once (1). So let us forget about both.

I shall assume an IFV with a crew of 2 and a maneuver squad of 1 plus 6, with its commander doubling in the third crew station (fig 1, page 20). The crew compartment proper has exactly the same layout and facilities as the small-crewed weapon platforms we discussed in Chapters 3 thru 5. In the rear compartment the front two men on each side are seated facing obliquely forwards, each station having a periscope and an NBC-proof weapon port. The rear pair of men have swivel seats and two periscopes and ports each, one facing obliquely forward and one facing rear. The two men next behind the driver have the additional task of replenishing the weapon pod's ready-round magazines from an externally vented hull magazine down between them and the driver.

The clue to the maneuver squad's wellbeing lies in a careful analysis of the threat to which the vehicle and its men are subject during waiting periods and in contact, and of the particular problem of remounting when chemically or radiologically contaminated. The "NBC threat" has become such a well-established cry that we are apt to think of it as a single entity turned on and off by a switch. This is not so. For starters we can forget about the "B" (biological) for forward troops because the incubation period is too long to meet the requirement of immediate disablement.

The most probable and most insidious threat is the **chemical** one - most probable for reasons discussed in my other books; most insidious because a single shell or bomb burst, or a spray borne on the wind from a distant aircraft, or put down by one flying nap-of-the-earth at transonic speed, can

instantly produce a concentration of nerve agent which is lethal even at the percutaneous level. In other words, this attack will inflict on anyone who is not **fully** protected from top to toe a syndrome of rapid and progressive mental and physical degeneration culminating in death after tens of minutes. Nerve gas casualties just have to be prevented, or at least held to the avoidable minimum brought about by human error, equipment failure or combination with other forms of attack (2). Their effect on the morale of those witnessing them is of a different order than that produced by gunshot wounds or, from what one knows, on the fringes of a nuclear attack. It strikes me as highly questionable whether morale can in fact be sustained in face of even the minimum practical casualty level.

Unlike chemical attack, the tactical use of **nuclear** weapons is going to be part of an extremely intense, conspicuous and rapidly evolving scenario. It would I think be possible to identify periods of nuclear threat, or at least its onset, separately from the chemical threat which exists over the whole theater the moment the opposition assumes a warlike posture. Provided the aggressor knows the defender's troops to be prepared and reasonably dispersed and protected, he is going to use nuclear weapons specifically as covering fire for the advance of his mechanized maneuver force. Once he detonates his first tactical nuclear weapon, he has to achieve his immediate strategic objective (like the capture of Bonn, Brussels and Amsterdam) while the defending governments are still dithering and initiating their ponderous procedures. This is a known and not improbable scenario.

So the real tactical nuclear threat is going to find the defender in one of three postures. Maybe - and to my mind not improbably - he is taken completely by surprise with his troops in garrison or wherever, thus making this discussion irrelevant. Or he is deployed in hides under chemical protection; and his reconnaissance observes the opposition infringing the frontier or activating some other tripwire. At this point he still has time to order nuclear alert and will in any event want to bring his mechanized force to immediate readiness to move - in other words mounted. Or again, the battle of the main mechanized forces may be approaching its crunch point when the aggressor goes nuclear; in this event the defending forces will already be on the move or deployed in battle positions.

In other words the "NBC threat" we were discussing in Chapter 4 was really a chemical threat. Given this, it looks as foolish to cram maneuver squads into tin cans as it does to divorce the crews of armored vehicle weapon platforms from their inherent protection and comforts.

Before we pursue this argument further, though, I want (for purely technical reasons which will become evident in a moment) to address the problem of men remounting after they have actually suffered chemical or radiological contamination, specially remounting in a contaminated area. The view generally held in NATO circles is that, once an armored vehicle's interior is contaminated by a persistent chemical agent or radioactive matter, decontamination is unfeasible or at least impracticable in the field. The Soviet Army has specialized equipment and teams either in its NBC defense battalions or one level further back (3). In this context as in others, the Warsaw Pact policy of formation reliefs offers possibilities which are not open to NATO. The implications of this question are so serious that I guess one should take a specific and balanced view rather than content himself with sweeping generalizations.

For starters we must accept that the outside of the vehicle, every nook and

cranny of it, will be contaminated, along with unprotected surfaces of external stowage and even (from experience with dust) stowage in external bins not specifically sealed. We must likewise accept that the engine compartment will become contaminated from the normal intake of aspirated air and maybe still more so if in situ repair takes place in a contaminated area. Only time and repeated steam cleaning and chemical treatments will reduce this contamination below the hazardous level. By contrast there looks to be no way the kind of crew compartment envisioned in earlier chapters, along with the electronics (in the broadest sense) and other control systems, can be decontaminated without being seriously damaged. So the policy has to be to keep these areas clean as far as humanly possible and treat vehicles with seriously contaminated crew compartments as subjects for deliberate reclamation or cannibalization.

One has to admit that the same goes for the rear compartment of at least the older armored personnel carriers. But this is largely because of the way they are designed. Once there is a plastic liner (page 25) ample "easy-clean" technology is available from the domestic and food processing/transport fields. Provided that the electronics and weapon pod are screened by bulkheads with appropriate access panels, that seats and other fittings are easy to strip out, and that all equipment is suitable for steam cleaning, the rear compartment could be made reasonably quick and easy to decontaminate. Thus contamination could be accepted in a tactical emergency, though evidently not as a matter of routine.

To anticipate a question, let me deal briefly with the special case of the maneuver squad commander, who occupies a place in the crew compartment proper (fig 1, page 20). Evidently the normal remounting drill must provide for him to mount first in the right hand file. Normally he goes straight back into his "crew" station. If the squad has to remount contaminated in a tactical emergency, the squad commander can remain in the right front place, its normal occupant moving across temporarily to the weapon pod loading area (4). Since the rear compartment is already contaminated, the squad commander can progressively discard his protective clothing into it as he moves through to the crew compartment, where he dons a spare set in the normal way. Maybe I should apologize for boring the reader with details of this kind; but experience tells me that it is just on such details that designs and SOPs (5) alike stand or fall.

Contaminated men remounting in a clear area can simply discard their protective clothing and carry out personal decontamination drills (some of which call for mutual assistance) before mounting. However the importance of keeping the rear compartment clean is high enough to justify an effort to provide a means of remounting clean in a contaminated area when time allows.

The need is for an airlock similar to the blackout lock fitted to the rear of some command vehicles (6) but capable of being extended and retracted from inside or outside the vehicle. This is essential both to maintain overpressure inside the vehicle for long enough with the rear doors open and to avoid recontamination. Everything except the frame should be in an expendable pack in a bin on the outside of the rear doors. To mount, the squad pulls out the frame, opens the rear doors, slides in the side and rear curtains and lays a groundsheet. The airlock should hold two men, because some types of protective clothing call for assistance in personal decontamination to be given to a "half clean" man by one who is still "dirty"; in the converse case assistance can be given from inside the vehicle.

The procedure is self-evident. Each man strips his protective clothing from the top downwards, carrying out decontamination procedures as required at each stage, and sits in the rear of the vehicle to kick off lowered trousers and

overboots. The next man kicks the discarded clothing out of the lock before decontaminating himself. Once everybody is in, the airlock frame is retracted from inside the vehicle, this action automatically discarding the curtains.

Let me conclude this digression with a general point. Expendable equipment offers an effective solution to many problems of modern high intensity operations. In war, expenditure and unplanned wastage is so great that the financial and logistic cost of minor expendable items is scarcely significant. By contrast expendable equipment is anathema to peacetime financiers, so armies often get landed with an expensive, unrealistic solution and suffer a loss of combat effectiveness. After all, the British Army went on having its socks counted monthly by a major until the cost of the major's time rose to about ten times that of the socks counted!

Having thus cleared the ground, we can start thinking realistically about how the maneuver squad is going to live. We already explored in depth the problems of crews living under "NBC threat" (Chapter 4), so we may as well start with this condition. We will accept that nothing can replace the vehicle's armor as protection against the nuclear threat, but that protecting against the **chemical threat only** during long waiting periods is an acceptable risk. Six men require less sleeping and living space than nine. The commander, maneuver squad commander and driver should live in the crew compartment just like the crew of a weapon platform, except that they would feed with the squad. Since access along the center gangway of the rear compartment is a must and the fittings of this compartment have to be kept simple for ease of decontamination, nobody should sleep there.

I rejected inflatable equipment for crews (page 24) because of the need to crash out and because they slept off the vehicle only in the absence of a chemical threat. I believe it is the answer, though, for the "**protected penthouse**" a maneuver squad needs; for one thing punctures will quickly disclose themselves. But there are four stronger reasons. The inflatable principle helps in handling the relatively heavy materials needed; and the layer of air provides good thermal insulation. Second, however well trained and armor-minded the men may be, getting a squad in and out of bivouac is a more ponderous business than bedding down or rousing a crew. Third, if the squad has to mount on nuclear alert, or to crash out, they will have to leave the penthouse behind. Fourth, if the penthouse is contaminated, they will have to abandon it anyways.

The inflatable tent should have a front fly, which forms a porch in the normal way when the squad is in the field and not under chemical threat. I would see this tent with two sleeping wings for three men each, and cooking and washing/toilet compartments at the center opposite the fly - very like a commercial family-size frame tent, in fact, but inflatable. The front fly would be arranged with zippers so that it could quickly be reshaped to form a tunnel zipped down over the tent opening (also zippered), stretched over the airlock frame and the open back doors of the vehicle, and suitably sealed. We shall discuss cooking in Chapter 9; for nine men it would have to be based on bottled gas in the tent or outside, with limited electrical facilities on the vehicle. I would envision a toilet fitting with a flip-up lid and basin over a seat (see page 34). A funnellike pan would lead diagonally downwards through a sleeve in the tent wall with an appropriate seal. A flap for trash disposal would be needed in the adjacent cooking department. Unless the hide was contaminated or under immediate threat at the time of entering it, a pit for sewage and trash would have to be dug, and provision made for chemical treatment of its contents via the WC.

Since the IFV's battle weight is likely to be lower than those of the primary weapon platforms of the same family, there should be enough weight margin to carry a larger **deployment roof pack** (page 34). Bulk is probably the limiting factor, but it should be possible to carry double the quantities of water and fuel of the weapon platform vehicles (1200 l of water and 400 l of DERV). This would allow 20 l of water per man per day as against rather under 30 l for the three-man vehicles; but there should be a relative saving of water for cooking and dishwashing with the larger group. There is in fact no reason why IFVs should not tow a "**deployment trailer**" of reserve water and fuel and abandon it on moving out to battle positions. This could even be a cheaper solution than roof tanks for all vehicles.

For the IFV will have a good deal else to carry if it is to offer accommodation with full chemical protection outside the vehicle. Taking various tradeoffs, one might guestimate that the tent and tunnel will need an NBC protection unit of around the same capacity as the vehicle system - and of course equivalent air conditioning and heating resources in extreme climates. I would see this unit, with its add-ons if necessary, zipped into the tent wall in the cooking compartment. My instinct on balance would be to power it from the main vehicle supply with additional battery capacity to maintain an acceptable silent period. I do not like either the implications of setting up a "chorehorse", its reliability or its continuous audio signature. I would likewise favor having a standard built-in unit for the whole vehicle family and boosting capacity by supplementary units, rather than fitting IFVs and CSVs with a permanent system of higher capacity. This is an area, though, which requires detailed design exploration. Whatever happens, the IFV's "waiting period" fuel requirement is going to be roughly double that of the weapon platforms (7).

I see no need to repeat the arguments of Chapter 4. The maneuver squad is evidently subject to exactly the same physiological and psychological stresses during buttoned-up waiting periods as the crews. The loudspeaker(s) and monitor unit(s) which will in any event be needed in the rear compartment can be made dismountable and remoted into the tent, along with light and power supplies. If this is done, mounted sentry duty can be carried out from the tent as well as from the crew stations, and a great deal of shuffling about will be avoided.

Maneuver squads will have much more freedom of movement than crews. They need not confine themselves to isometric exercises and they require a more physically oriented (team game-linked) team spirit than crewmen. A videotaped physical education program, matched to and carried out by the squad as a whole, is therefore preferable to individual programs. Weapon training and related skills can be exercised by means of a "TV games unit" linked into the system; for other training, squad and crew share the same program.

The problem of stowage on APCs and IFVs is always a serious one; with proper provision for men to live in the field under normal conditions and NBC threat, it will become more acute still. The rear compartment needs to provide stowage for the squad's dismounted combat clothing and equipment (including the commander's); changes of clothing; personal effects, weapons and ammunition; reserve packs of NBC protective clothing; and some rations. With only six men in the rear compartment of a relatively large vehicle, this should not prove too difficult.

External stowage is another thing again. Nobody will need "outside" sleeping bags (page 24). The inflatable tent replaces the crew tent (page 24), the crew taking turn and turn about with members of the squad if they want a change of environment. Only the two permanent crew members will need survival packs, the equivalent for the squad being carried in their combat rucksacks (page 52). But the tent will not be overly compact; its essential fittings, including the NBC protection unit (and possibly an air conditioner or heater) will be relatively bulky and awkward. My guestimate is that roof stowage bins and/or racks will have to be accepted at the cost of depression of the weapon pod over the rear 180° - but not of overall height. All-around vision from the sensor heads on top of the weapon pod will be almost unaffected, and there will be a rear lookout when the squad is mounted; so I guess this is acceptable.

Finally there is the question of concealment. Under NBC threat the complex of vehicle, tunnel and tent will be awkward to hide. When the tent and vehicle are separate, the movements of men around the tent and between vehicle and tent will be far harder to control than those of a small crew. In inhabited areas, it will probably be normal to back the vehicle into a building and rig the tent under cover. Elsewhere large pits may have to be dozed out. The need for concealment calls for a remote sensor head of limited capability to obviate the need for a dismounted sentry under NBC conditions; and occasionally (if the building used has a significant screening effect) for a remote antenna.

In this chapter I have been forced to go into a deal of detail. Much of this will be controversial, and some of it may be impracticable or even, for design reasons, self-contradictory. But I believe I have driven home the point that the way mechanized infantry or the maneuver squads of composite units live in the field, notably under "NBC" threat, needs a fundamental rethink.

Notes

1 Cf. "Mechanized Infantry", page 68

2 Soviet and Western studies seem to agree in putting this level at 10 to 15 %, probably the combat equivalent of the (much lower) residual risk of accident or failure in complex systems.

3 Battalion equipment looks as if it might be suitable for use on armored vehicle interiors, but I do not have any firm evidence on whether it is considered suitable or whether battalion teams are trained for this task.

4 In fact there is likely to be space to give the squad commander an emergency position without displacing a member of the squad.

5 Standing operating procedures

6 As distinct from the much larger "penthouse" sometimes provided too.

7 The optimum solution depends on whether a modular concept is adopted (Chapter 15). In a dedicated IFV/CSV, a single system for the whole armored volume would probably be best; in a modular family there must be one system for the crew compartment and a second capable of covering the needs of rear compartment and penthouse.

CHAPTER 7

The Command Vehicle Problem

If a satisfactory mount for the commander of a mechanized force has so far been found, I have not encountered it personally or vicariously. So it may be best to take two bites at this cherry. The first, taken here, is the provision of a suitable environment. Then in Chapter 20 we can stand off and take a broader look at command and control techniques.

Any command vehicle which is not lookalike invites and normally receives speedy attention. The turret of a tank just does not offer the facilities for sustained control of a complex force. The rear compartment of a command vehicle (CV) limits the commander's information to map and radio, and prevents him from exercising and being seen to exercise forward command. The conventional solution is for the commander to go forward in a tank or other "rover" vehicle while his deputy or exec maintains continuity and coordination from the CV. This is just fine as long as the battle proceeds according to plan, so that the commander really is where it's all happening. But a sudden change of situation - like penetration to a flank, a switch of direction by the enemy, or new orders - leaves the command and control arrangements badly off balance. The time the commander takes to get back to his CV or to the new focal point will be largely wasted. This may add up to a loss of tens of minutes - a period unacceptable to the tempo of the nineties mechanized battle. (To anticipate a question, a chopper is not the answer unless it is airborne, in the right place and available - in which case it is probably being misused. Anyways its behavior will disclose it as a prime target.)

I believe the command and support vehicle (CSV), a command variant of the IFV in the family I have postulated (page 20). solves this problem. So I included it in the composite platoon of the organization I postulated in my previous books (1) and paired it at higher levels. This vehicle is an IFV lookalike with the same protection as the primary weapon platforms. The commander's and deputy commander's stations offer the same vision, electronic/optronic sensing and fire control facilities as the IFV (and *mutatis mutandis* the primary weapon platforms). The armament is suitable both for local defense and for target and route indication by tracer or shell burst - probably an important factor under electronic warfare conditions. We already found (page 43) that the fittings of the IFV rear compartment need to be removable. A slight extension of this thinking opens up the option of a family of plastic-walled slide-in rear compartment liners fitted and equipped for the various levels of command and specialized roles like artillery observation or command post (2). We might bear in mind too that this family of vehicles can

be expected to have at the very least the mobility currently associated with light tracked and cross-country wheeled vehicles.

The composite platoon commander should in fact be able to carry out tactical command from his station in his fire support tank (FST), only needing to switch vehicles for lookalike reasons when he wants to lead a dismounted attack (3). At higher levels the tactical commander wishing to make a plan needs only to pull back behind the nearest cover, implement an SOP that will put his deputy or exec in charge of the current battle and his own signals team onto the rear link, and move through from his forward station to the rear compartment (leaving the vehicle to be moved and if needs be fought by the vehicle commander and driver). It would be feasible to display map images on the monitor in the tactical commander's forward station; but, transmission problems apart, the equipment needed to move the camera by remote control is rather bulky and would interfere with normal use of the main map. Additionally it is probably sounder psychologically for the commander to detach himself from the events surrounding him when he is planning ahead.

I envision the CSV as having a complement of between five and seven depending on the precise role. Over and above the vehicle commander, driver and tactical commander (or deputy or exec), who form the "crew" in the sense we have been using this term, this allows for two reserve crewmen for other vehicles (doubling as additional signalers if need be), a medical orderly and a technician (Chapter 11) at platoon level; and up to four signalers or other specialists at higher levels or in specialized roles.

The living requirements of this complement would be well served by the arrangements already proposed for the IFV proper (Chapter 6) with one slight modification which it would probably be economic to incorporate on all inflatable tents for IFVs and CSVs. This consists of zippered flaps on the end and rear of the sleeping compartments, allowing two or more tents, each "docked" with its vehicle under chemical threat, to be combined into complexes of variable shape and size. These additional flaps could be permanently sealed with tape on tents issued to IFVs; anyways I have tacitly assumed that all zipped joints would have offset inner and outer zippers to ensure adequate sealing. Inflatable or folding chairs and folding tables would need to be carried. If the extra furniture required for one "ops room" tent is carried on a pair of vehicles, the external stowage space should suffice. The possible needs to "crash in" to the vehicles on nuclear alert and to crash out of a position preclude stripping of the rear compartment to furnish the tents.

I have excluded the possibility of an officer's mess for headquarters mounted in armored vehicles and deployed under actual or potential NBC threat. In my experience this is no loss, field messes being mostly a means of ensuring that officers live less comfortably and eat less well than their crews. But the question of the commander's privacy and comfort is a key one; and from battalion level upwards some commanders may feel a need to distance themselves in some measure both from their staff and from the enlisted men of their headquarters team. I believe that with a "penthouse" complex of at least three CSVs this can be arranged by setting aside the end sleeping compartment and central part of an "end" tent for the commander. He also has the option of retiring to his "crew" station in his vehicle.

I mentioned above the use of the CSV's gun and cannon for route and target indication, and I should like to close this brief chapter with a mention of a problem I have not seen discussed elsewhere. The combination of the chemical and electronic warfare threats may face combat team and lower commanders of

mechanized forces with a severe problem of communication. If net radios are out, the commander and his subordinates may be unable to converse in person without the virtual certainty of contaminating two vehicles. The sophisticated solution is a very short range, highly directional laser-beam telephone, probably combined with an intervehicle alarm system. The unsophisticated one is the use of indicator tracer or shell, signal flares and - at considerable risk to the maker of them and his crew - hand signals.

There would look to be a place for a solution between these extremes. Knowing the great difficulty of teaching armor signalers Morse and, as a yachtsman, the difficulty of communicating by lamp without constant practice, I suggest this is a nonstarter. Likewise semaphore proper (as used by British tanks in WWI). But a single semaphore arm offers **seven** characters (the cardinal and subcardinal points excluding south, so to speak). An "**all-around traffic light**" pillar with red, amber and green also provides **seven** characters, or **fourteen** with fixed and flashing modes. I think in fact there are just **seven** pairs of essential basic tactical and fire control commands, maybe these -

move	halt
advance	retire
right	left
conform	do not conform
close	fan out
fire	cease firing
add	drop

Crewmen should be able to learn these signals, specially if they are paired in fixed and flashing modes (as above). Anyways they could be set out on a label in the crew station. A set of seven similar colored signal flares, used singly for "fixed" and in pairs for "flashing" could extend the range of this simple system. Both systems are valid by day and night.

Maybe if the insides of future armored vehicles look like amusement arcades, the future armored battle will come to resemble the pinball machines these contain.

Notes

1 **Antitank**, Chapters 20 and 23, and Appendix.

2 This is in fact the first move towards the modular concept discussed further in Chapter 15.

3. **Mechanized Infantry**, Chapter 5 and fig 5.

CHAPTER 8

Clothing

The extraordinary "pilot in a foxhole" condition in which the tanker has traditionally found himself shows up well in the efforts of various armies to clothe him suitably. With the possible exception of the British "tank suit" of the fifties and sixties I have never seen anything approaching a satisfactory solution. Nor can I envision one until the crewman's absurd situation is rationalized. This calls for four changes -

protective lining of the crew compartment

biotechnological design of crew stations, including proper seating (Chapter 3)

controlled microenvironment (Chapters 4 and 5)

no work outside the vehicle in the field (Part 2)

Having thus given armored vehicle crew aircrewlike status in the field, we need to define the categories into which they fall -

crewmen fight and live mounted, dismounting only in emergency

maneuver squads move in, and do some fighting from the rear compartment of their vehicle; but basically they fight and live mounted, or in an extension of their vehicle (Chapter 6)

tactical commanders normally fight and live mounted but may switch mounts or dismount (Chapter 7)

additionally **everybody** may have to wear NBC protective clothing when mounted or dismounted

In temperate climates, the heat generated even by modern subsystems operating in the standby state plus the measure of environmental control inherent in, or deliberately built into the NBC collective protection system (plus the use of a heater in winter) should hold vehicle interiors and inflatable tents at something around 15-20°C (cf. page 38); no humidity problem is likely to arise. So we can envision a common **temperate mounted dress** for all three categories. This might consist of a cotton cellular singlet and boxer shorts, summerweight slacks, a lightweight (cotton-based) polo-necked sweater, thin

(wool/synthetic) socks and nonslip shoes with a quick-acting fastener. The lower legs of the slacks need to be gusseted and zippered like a tracksuit so that they give freedom and ventilation when mounted (with shoes) but fit comfortably inside boots. A warmer pullover of the type now worn by many armies should be available. We already discussed the question of disposable "under-underclothes" to absorb sweat and such (page 30).

There are arguments for a one-piece garment (like a coverall), but I suggest the requirements of living buttoned-up (vehiclewise!) argue for a two-piece design. **All** items of clothing likely to be worn as outer garments on the top half of mounted men's bodies must have a **sling** between the shoulder blades for lifting a wounded man out and be reinforced accordingly. This emergency sling needs to be tack-stitched into light garments and in a zippered pocket on heavy ones.

In **cold climates** and severe winter conditions, the underclothes are replaced by a string vest and woollen or string long johns, and thicker socks are worn; the pullover is again a reserve. The wearing of "thermal" underclothes may call for an interior temperature lower than the 13°C minimum suggested earlier (page 38). The only change required for **hot climates** would be replacement of the polo sweater by a long-sleeved T-shirt, along with provision of an expendable cotton sweat scarf (in place of paper scarf) to protect the nape and the sides of the neck from being rubbed by the NBC protective suit.

Apart from ready and spare protective suits (of which more in a minute) and the warm pullover, the only item of dismounted clothing carried in the crew compartment is **boots.** To minimize dirt in the crew compartment proper (Chapter 10), the boots should be kept in an open-sided locker, located so that the wearer can step straight into them and then onto the first foothold for dismounting. Boots are a critical item in any army's dress, doubly so in this case. We need to forget about the work boot or shoe intended for heavy tasks in garrison, and the marching boot. Both these are purpose-designed; the mechanized force needs a dedicated boot too, and the commercial market provides a wealth of ideas.

The most suitable basic type of boot is probably the jungle boot, but this needs a great deal of modification. The sole must be nonslip, probably of the "semicommando" type (1), and have a shape and rigidity which make the NBC overboots as easy and safe to move about in as possible. The upper should be fully tongued and waterproof. It should reach to about normal jungle-boot height and be fitted with at least three adjusting straps captive in self-locking buckles (so that support can be applied to the instep alone, instep and ankle, or instep, ankle and lower calf). The boot should have a waterproof pull-up soft top, similar to those of modern sea boots but stretching most of the length of the calf, with the usual drawstring at the top. Like short (old-fashioned) sea boots, the boot should be shaped so that it is easy to insert a wool stocking. This stocking needs to be secured at the top of the boot proper and of the soft extension, so that it does not ruck when the boot has only one strap tightened or the soft top is left down. Finally, some cushioning of the kind found in modern hill-walking and climbing boots is desirable. Men must be trained to harden the skin of their feet by regular exercise, and to keep it hard by rubbing with spirit. But remaining mounted for long periods is inevitably going to lead to excessive perspiration with softening of the skin and frequent minor skin conditions of the foot. And these periods may be followed rather suddenly by rugged evasion and escape conditions!

Temperate combat dress for maneuver squads and tactical commanders should evidently be designed in conjunction with mounted dress. I would see these men wearing mounted dress out of contact, specially during long moves or waiting periods. When mounted at combat readiness, they would change into boots (as described above) and combat dress slacks. (The level of dirt associated with boots has to be accepted and is in fact acceptable in the **rear** compartment of IFVs; tactical and maneuver squad commanders will soon learn the importance, if only for their own comfort, of cleaning or changing their boots as they reenter their own crew stations from the rear or via their hatch.) As the reader will have spotted in the discussion of crew dress and boots, dressing and undressing needs to be made as easy as possible, so that each action can be performed in a single movement or a short and easy sequence of movements. Thus the **combat slacks** should be tapered so that the boots can be put on over them without rucking. These slacks would need the usual outside pockets for maps and magazines and should be of the typical showerproof camouflage-patterned material normally used for combat dress.

Of more interest and importance is the **combat jacket.** It may help to start by drawing an analogy with the modern oilskin jackets for yachtsmen which incorporate a lifejacket, a securing harness and sometimes a tool holder for spike and pliers. With these jackets the skipper (for instance) can be comfortably dressed below and be completely ready for deck work **in a single motion** when he is called on deck. The military equivalent of this is a **combat jacket with battle-order equipment built into it.** This dispenses entirely with the need for harnesslike equipment, the buildup to marching order being achieved simply by adding a rucksack carried in the compartment (roughly the equivalent of the crew's survival packs, cf. pages 25 and 46).

One has to take a tradeoff somewhere, and I believe the right one to take follows from the rationale of reducing the maneuver squad to 1 plus 6. These maneuver squads of composite units are **not** normal infantry. They are trained and equipped to fight in close conjunction with armored vehicles and in the neighborhood of their own IFVs. They may occasionally be regrouped into company-size concentrations (for blocking missions and the like), but they will still have their IFVs with them. So they do not need cumbersome squad weapons (or ammunition for them); or at least they can normally leave these weapons on the vehicle. The same goes for these men's equipment. They will mainly be required to dismount for short periods only and to fight near their vehicles. When this is not so, as in deliberate dismounted operations and in evasion and escape, they take their rucksacks and if appropriate their squad weapons; they are then completely equipped. The risk is that they will dismount lightly equipped and be unable to get back either to their own IFV or to another whose maneuver squad has suffered casualties. I believe this risk represents a fair tradeoff for comfort when mounted, speed of dismounting and remounting, and agility on the ground.

In these terms they will require to carry only items like these -

on each man	short bayonet and attack/digging/clearing knife (combined)
	individual weapon ammunition (some in slacks)
	fragmentation hand grenades
	small flask of water (say 0.25 l)

	booster snack (carbohydrates, preferably glucose, probably chocolate)
	personal decontamination kit (including atropine "autoject")
	field dressing
	ballpoint and notepad
spread over squad	radio
	map
	hand-bearing compass
	signal pistol and cartridges
	antitank grenades **or** limpet mines
(plus as required)	minelets
	trenching tool(s)
	marking tape

I see no difficulty in accommodating the personal items in pockets round the lower part of the jacket and/or on the slacks, leaving the normal trouser pockets for handkerchief, gloves and the like. Personal effects could be left in the pockets of the mounted slacks - a good practice anyways from the security point of view. The larger squad items could then be accommodated either in poacher pockets above waist level or in external patch pockets on the chest.

Everybody, whether or not they require a communication facility (cf page 23), needs to have a **crash helmet** and to wear it when moving mounted. A **steel helmet**, as is already the case in many armies, needs only to be a sheath fitting over this.

The modification of this dismounted combat dress I would see in extreme climates are few - mainly replacement of the jacket with a **parka** of similar design, along with a heavy oiled sweater to be worn over or in place of the standard pullover, for **cold climates**; and replacement of the showerproof material of jacket and slacks by an ultra-lightweight, porous, maybe cellular (but insect-proof) cloth for the **tropics**. Fully enclosed **snow goggles** are needed for cold climates and a **cap**, aimed primarily at sun protection, for hot ones. If the water flask and booster ration are the same size and shape, extra chocolate could be carried in the cold and extra water in the heat.

For **crewmen** combat jacket and slacks (including personal items), along with a set of NBC protective clothing, would form a separate expendable pack attached to their survival rucksacks (page 25).

The third set or layer of clothing needed is **individual NBC protection**. Most advanced armies now have effective suits and much improved respirators, the current British equipment being widely considered the best. There will doubtless be evolutionary improvements, notably to respirators, but no radical change seems likely unless and until physical screening gives way to

prophylactic medication. This remark is worth making because reliable prophylaxis against nerve agents, long-term and free of unacceptable side effects, could take a great deal of the sting out of the chemical threat. A respirator which prevents ingestion or inhalation would then give complete protection against hydrogen cyanide, arsine and lower grade non-persistent agents. With modern aids to decontamination and treatment, the risk from the percutaneous action of low grade persistent agents (such as mustard gas) could probably be accepted without resort to special clothing. The physiological action of all nerve agents is similar. Atropine blocks it temporarily, but is otherwise a highly toxic substance. It would not be too surprising if, from the whole spectrum of research into chemotherapy, antirejection treatment and genetic engineering, an acceptable prophylactic should emerge.

Meanwhile, though, protective clothing and all its drawbacks are with us; and even then we should still need it for the less probable radiological threat. We have already discussed it in several contexts (see in particular page 42 et seq) and shall be returning to it in Parts 2 and 3. This clothing presents a set of paradoxes. It must be impermeable even to vapor from the outside but must not (even in unfavorable conditions) produce an intolerable micro-environment for the wearer. It must be cheap enough to be expendable (even on a limited scale in peacetime) and tough enough to withstand dismounted combat; and it must pack small enough for ample spare sets to be carried in the limited space available. It must be large enough to fit over other clothing, well-fitting enough not to hamper movement and tolerant enough of its wearer's shape and size for the sizing problem to be minimized. It is really hardly surprising that even decades of research and development have failed to produce an acceptable solution.

The particular paradox I want to air here is where priority items like magazines and grenades are carried when protective clothing is worn. If the protective jacket (or upper part of a coverall) has both slits and pockets, there is no problem until the wearer actually becomes contaminated. This I suspect is the point at which development thinking and training stops or at least dithers. But the opposition is evidently prepared to fight in a contaminated area, so NATO has to be too. The nub of the problem is that a man's glove will be contaminated and will thus contaminate anything he touches. If he takes his glove off, he has to insert his bare hand through a slit of which the outer edges may be contaminated.

One solution, adopted in some sets of clothing, is to have an inner and an outer glove, the inner providing limited protection. This allows magazines and the like to be kept in their normal position in combat clothing (or conventionally in harness equipment) and taken out without any significant amount of contamination being transferred to the combat clothing. The same expedient is useful to those who have to perform intricate tasks, like reconnecting electrical leads or hydraulic pipes "by feel", under contaminated conditions. It may be helpful in personal decontamination procedures too. Another possibility is to have compartmented pockets in the protective jacket. These hold one magazine or whatever each and are accessible from both inside the jacket and out. If the item is not used, it remains uncontaminated. Expendable items which are used are discarded. Others, like magazines, are placed in another pocket after use, transferred to a special external bin on return to the vehicle and dealt with when suitable facilities are available.

This chapter reinforces lessons which echo through the earlier chapters of this book as they do through its predecessors. The clothing of a mechanized force calls for a radical and rational approach. It is yet another example of the

need for modern armies to think in functional terms like air forces have to. The problems raised here highlight the importance of looking at practice in other services and at developments in relevant commercial fields. Likewise they reemphasize the need for designer and user to get their heads together, keep their minds open, test everything thoroughly under realistic conditions, and above all recycle ideas and products until both sides are convinced they have the right answer.

Note

1 I cannot find a universal name for this sole. It is increasingly worn for golf. The "commando" sole is a rubber composition sole with a deep tread of hollow diamonds and short longitudinal and lateral bars; the "semicommando" sole is similar but lighter and less deeply indented.

CHAPTER 9

Cooking Facilities and Rations

There is an evil school of logistic thought which insists on supplying tankers with dehydrated rations. Reconstituting even modern dehydrated products is a messy business, wasteful of time, effort and above all of precious water! What is more it denies tankers and all others who live on their vehicles an interest and means of self-expression which provide a significant boost to morale. Even apart from buttoned-up waiting periods under NBC threat, common misery is a state all too easy to lapse into in the field. It is a sign of poor training and shaky morale. As I remarked earlier, the crews who live best fight best. In the mechanized warfare scenario, rations represent a minute fraction of cost and logistic lift, so they may as well be tasty and match the need. I suspect that, like other human factors, the problem has never been thoroughly analyzed and recycled between producer, logistician and consumer.

There are five situations in which the men of a mechanized maneuver force may want to feed themselves in the field -

leisurely meals outside the vehicle

leisurely meals buttoned up

hasty snacks inside the vehicle (on the move or during lulls in combat)

booster snacks
(for maneuver squads and others temporarily divorced from their vehicles)

evasion and escape (and the odd protracted dismounted operation)

The first three of these are the normal ones; since it so happens that the armored vehicle family I postulated is manned in multiples of three, a 3-man pack is needed. (The chaos that arises if packs do not match the number of men is quite simply unacceptable during buttoned-up waiting periods or when the running replenishment technique (Chapter 13) is used.)

I suggested elsewhere (1) for a number of technical and other reasons that active service rations should be handled as a subcommodity of ammunition. If this is done, there is no problem about maneuver squads and other dismountable elements drawing booster snacks (page 52) on an as required basis. Normally manpack survival rations would only need to be turned around

within their shelflife under the prevailing conditions; occasionally long-lasting dismounted operations might call for bulk issue of them. Studies I have done elsewhere suggest that the smallest number of men likely to be hived off for an operation of this kind is around fifty, so that packaging requirement is for the multiple of fifty represented by the number of days' rations carried in the rucksack. Before probing these rations and supplements further, though, we need to look at two related problems.

The first of these is **cooking facilities.** With gasoline virtually obsolete as a military fuel, there is no point in carrying gasoline or kerosene for cooking. As well as being dangerous, both these liquids have undesirable properties by way of smell, taste, oily residue and discoloration (kerosene), and incompatibility with the human skin. So one comes back to the yachtsman's argument - bottled gas v. alcohol. Bottled gas is heavier than air; if it escapes, it sinks to the bilges of small boats, forming an explosive mixture. Even in yachts, which have very limited electrics and do not as a rule get shot at, bottled gas is a frequent cause of major accidents. In an armored vehicle the risk would be completely unacceptable. The same risk is not present in or near the proposed crew and maneuver squad tents (pages 24 and 44), specially when the inflatable tent's atmosphere is being recycled and cleaned by the NBC collective protection unit. Thus bottled gas is reasonably safe as long as it is stowed in a vented external bin. I must admit to prejudice here; as a yachtsman I favor bottled gas and extremely strict safety drills, because I think the risk of flash fires with spirit stoves is much higher, though admittedly less serious. Despite decades of development, spirit stoves remain temperamental animals needing skilled handling. I would not consider using one inside an armored vehicle; and the risk of fire outside it, specially in the inflatable tent, is significant. Additionally bottled gas is easy to move and distribute.

If bottled gas is adopted, standard rechargeable cylinders (of a size to be calculated) can be used for stoves carried on the vehicles, and expendable cartridges for the manpack role. There is a vast range of suitable stoves and associated fittings available on the commercial market. Provided they have vacuum bottles and jars (as they must), a crew of three could look after itself very well with a 2-burner stove and a collapsible oven of the kind which is placed over the burners. IFVs and CSVs should carry one of the smallest size of compact unit with a hob and oven designed for small boats, campers and trailers. These normally do not require a flue; but trials would be needed to check whether the air ciriculation in the inflatable tent under NBC conditions sufficed to prevent a buildup of carbon monoxide.

The best means of cooking on the vehicle, already practiced in many armies, is electricity. The hours I have spent trying to scrape solid matter off the inside of the Centurion boiling vessel or watching others do the same suggests to me that two utensils are needed - a plain stainless steel boiler, and a nonstick pot with a lock-on lid for boiling, stewing or frying. Assuming the size of these utensils matches one "brew" and one main course for the crew respectively, the vacuum bottles carried should have a total capacity twice that of the boiler, and the vacuum jars should together hold the same as the pot. (This is a rule of thumb I in fact learned from sailing and wished I had known when I was spending long periods living on a tank.)

Commercial products may not always be robust or reliable enough to meet these requirements as they stand, although modern soldiers seem to use them with complete success on various forms of arduous training. But the commercial market shows the right approach. With a few exceptions, military cooking

equipment is needlessly large, heavy and noisy to carry about and use; also it is far too inflexible to produce the kind of results that United States C Rations or British Compo merit.

Canteen supplies in the field always did pose problems. A situation where the bulk of the men in a force live on their vehicles does not make these any easier; the NBC threat makes them tougher still; and modern trends and thinking about narcotics raise some rather broader issues. By narcotics I mean not "drugs", which must be kept out of armored vehicles at all costs, but tobacco and alcohol.

As long as it is clean (see Part 2) the inside of a diesel-fueled armored vehicle does not present enough of a fire hazard to justify a smoking ban on safety grounds. By contrast, having been a heavy pipe smoker for years until I gave it up seven years or so back after a severe attack of bronchitis, I now shudder to think what I must have inflicted on nonsmokers among my staff and specially on my command vehicle and yacht crews. The broad trend, in Europe at least, is running markedly against smoking in the presence of others. Contrariwise one learns of a series of scandals concerning tobacco, drink or drugs in various branches of the armed forces of major Western powers. This problem ties up with aspects of physical fitness and character training which go well beyond the scope of this book; and one would hope to find a high proportion of nonsmoking crews and squads. Once again, though, the rub comes in the prospect of long buttoned-up waiting periods. However much is done to "reindividualize" this situation, it will remain a highly stressful one - not one, I guess, in which it makes sense to deny someone the right to smoke. Then again, sending up large quantities of cigarettes literally with the rations encourages heavy smoking before and during operations, as well as being a major factor in the growth of a black market behind the combat zone.

Medical opinion swings so fast and violently these days that it is hard enough to keep pace with it as an individual, let alone to use it as a basis for policies in this difficult psychosomatic gray zone. At the time of writing alcoholism is a serious and mounting problem in most Western countries (2), specially among women and the young, who turned to alcohol and away from drugs in the seventies (and now look like starting to turn back again). Against this, alcohol at the "moderate social drinking" level is medically regarded as markedly less harmful than any other sensual pleasure including eating (3) - but excluding of course sex, recommended by many doctors as a panacea, but unfortunately hard both to arrange and to execute in armored vehicles!

All this being so, I at least would be opposed to a maneuver force going dry in the field, even if this policy was enforceable among ground troops. A reasonable allocation of alcohol of the kind one finds in the Royal Navy (4) or in some countries' military hospitals - may be two cans of beer and a double tot (say 75 ml) of spirits a day - might well confine black market booze, moonshine, wood alcohol and antifreeze to the few hard cases. Again there is the problem of accumulation through issue to nondrinkers and all the ramifications of this.

The only solution I can see to these problems is to keep cigarettes and alcohol out of the rations (making men pay for these as they do for other personal necessities) and to arrange for crews to fill out a weekly order form based on individual wishes, just as one does when victualing a yacht. These goods, along with mail, would have to be specially delivered during waiting periods in hides. On active operations, they would be handled along with IFV/CSV

ammunition as a platoon issue during replenishment. The immediate relevance of this discussion is to determine what should and should not be included in the rations.

In my experience, exchange visits involving enlisted men can always be counted on to throw up one problem - the total inedibility and/or inadequacy of the host's rations. I guess rations are about as hard to standardize as traditions. But there is one powerful trend in common among the armies and militias - four inside NATO and three outside it - likely to make a real contribution to the defense of freedom and Western values. Their members have high and steadily increasing expectations; in the socio-economic groups from which the bulk of armored vehicle crews and their supporting arms and services are most likely to be drawn, food plays a large part in these expectations. So anybody looking to "rehumanize" life in an armored vehicle, whether under NBC threat or not, will do well to have a rethink about rations.

In view of what I just said about national tastes I had better be careful. Nonetheless I have lived long and gratefully on United States C Rations, but longer and considerably more appreciatively on British Compo. Where I think this has the edge (apart from the size of pack) is in planning. Their creator, like a better known one, evidently rested on a Sunday, for there never were (as I recall) more than six menus (A through F); and some postwar vintages, presumably celebrating the five day week, had only A through E. But by saving up and a bit of bartering one could set aside a really good meal to be eaten when opportunity arose. Then again - with the odd exception just to prove the rule - the quality of all kinds of food was excellent. When sailing I have sometimes bought Compo (at no small expense) because, even in the seventies, one could not get the same quality of canned foods on the British or German civilian market - or even at the United States Commissary (5). The other notable asset of Compo is the number of items, like soups and traditional British puddings, which are equally good as a course in a meal or as a snack - specially the puddings which are delicious cold and have a deliberately high carbohydrate content. All this we can sum up as - variety, quality and flexibility.

As long as it contains enough snack options, I see no need for a mechanized force's ration to be specially easy to cook. Time spent on planning and cooking is time killed to good purpose; this activity represents one of the rather few means of self-expression available. We might link this thought and the basic qualities of Compo forward to modern technology and rising expectations to arrive at a "rehumanizing" philosophy on rations. As a point of departure we have maybe -

hot main meal items, which may require a fair amount of preparation

hot main meal items (eg soups) which double as snacks

cold main meal items (eg cheese, desserts) which double as snacks

snacks, sweets and savory but always high in carbohydrates (including some glucose sweet or the equivalent)

We will discuss instant soups later under the heading of beverages. These apart, there are some relatively new technical possibilities for increasing the variety and quality of main meal items. One of these, which combines excellently with the traditional practice of smoking food, is an appropriate

combination of **dry canning** (if necessary in inert gas) and **vacuum packing**. This opens a whole new range of foods with shelflives which, by the time this book appears, are likely to be compatible with military requirements based on a fairly high turnaround rate for training.

A second innovation is the availability of many flavors, seasonings, spices and herbs in forms which are easy to use. These too have long shelflives before their container is opened and reasonable ones after that. Many of them are commercially available only to the catering trade but could easily be made up into detailed packs. The value of these processed flavors is twofold. They greatly widen the possibilities of the staple canned foods which will inevitably form the basis of main meals; and they give considerable scope to individual talent - as I repeatedly stressed earlier, an important feature in morale under both "buttoned-up waiting" and "lull" conditions.

Any form of freezing is out, but it is worth noting that (as at the time of writing) a British firm with a worldwide repute for top-of-the-market foods still stays with canning in preference to freezing for most products, trade and retail alike. In the view of its experts, the use of improved production techniques and the flavors mentioned above are both tending to postpone the changeover point to freezing (for quality) and enabling step advances in the quality of canned goods. Given these facts and a sane philosophy on relative costs, there is no reason why the men of a future maneuver force should not be cordon bleu chefs and gourmets at one and the same time.

By the same token there is no reason why those who live and cook on their vehicles should not be trained and encouraged - as they now are not - to live off the country to the extent that they can. A few fresh items can do a lot for even the best of canned rations. As I remarked earlier, Duffy and Milo are caricatures - but like all good caricatures they contain a substantial grain of truth.

The quality of choice of **beverages** is maybe of even more importance to morale than good food. Soft drinks and fruit juices have become so much a part of life, specially among the younger generation of the most prosperous societies, that a limited proportion of them in their commercial packs are worth their weight and bulk just for the nostalgia value. Hot drinks are - psychologically at least - so important to alertness, endurance and morale that I believe it is worth doubling up on them - canned ground coffee, tea leaves (or bags, according to national taste), drinking chocolate or cocoa and evaporated milk on the one hand; and the instant varieties, including fat-reduced powdered milk, on the other.

The same goes for soups - "full" canned (not condensed) soups for when time allows; and individual instant soups which can be made with water at vacuum bottle heat for moves and short lulls. Let me close the discussion of these principal rations by reemphasizing a point logisticians often get wrong. Given the degree of processing and preparation necessary for preservation - canning or long-life vacuum packing, that is - there is no useful half-way house between main meal foods and the quick, easy snacks like cheese and crackers, chocolate and an instant drink. I have encountered plenty of well-meant efforts to improve convenience short of going instant, but they never seem satisfying or effective in the armored vehicle setup (or the very similar sailing environment).

Finally a brief word on the manpack/survival ration, conventionally represented by the United States K Ration and the British "24-hour pack."

"Conventional" is the word here, and I reckon it adds up to a whole wrong approach. As I recall, the K Ration of earlier decades came in three colors (different menus) and labeled every item by meal and course, so one was reduced to eating by numbers. I have been very grateful for K Rations in my time, but I recall feeling an element of dehumanization even in the heat of the moment.

Sure, the British Raj "wore its dinner jacket in the jungle"; and there may well have been a time when even the feeblest imitation of "four square meals a day" was helpful to morale. But eating habits have changed radically, most of all in loss of regularity, and they are still on the move. These manpack rations are intended for men trained to use them properly in either of two situations. One is during short periods of rapid movement and/or intensive combat away from their vehicles. The other is in evasion and escape - when the rations a man can carry will in any event have to be eked out over long periods and supplemented or even largely replaced by fresh food of doubtful quality, often eaten raw.

The need is thus not for a set of meals but for an assortment of dietary units with, I would think, heavy emphasis on carbohydrates. Each type of unit should have a name for ease of reference - preferably an appetizing one - along with a secure waterproof label saying what it is and what it is for. Likewise, for the benefit of those able to make use of the information, its "Joule content" (as we now have to say, at least in the Common Market), its protein/fat/carbohydrate balance and its vitamin and other trace constituents should be shown.

The thinking underlying these suggestions is twofold. Men using these rations are likely to be leading extremely irregular and arduous lives and must eat and drink when they can. And the food carried may have to serve as a whole ration for short periods; to provide minimal subsistence over long ones; and to boost and balance low-grade fresh food over longer ones still.

With manpacking, dehydration and concentration become the order of the day, and all hot and cold drinks are instant. Water purification tablets must be included, along with a flavor to make treated water more palatable. Salt tablets are also important in hot climates (though there is a controversy over how they are best taken). On balance, a minimal gas cartridge heater should be included even in hot climates, although some men may choose to save weight by discarding it.

Finally, however good the normal and survival rations may be, they will be largely wasted unless men are thoroughly trained in their characteristics and use. The art of cooking on tanks always was a kind of folklore passed on by word of mouth; and its results always produced a very healthy rivalry. With the possibilities and problems which now exist, the need is to improve knowledge and skill without destroying the element of competition or preempting individual flair.

Notes

1 **Antitank**, Chapters 15 and 24.

2 Still more so, of course, in the USSR.

3 Between drafting this chapter and revising it for press, I learned of a further swing of medical opinion **in favor** of moderate consumption of alcohol on health grounds!

4 The Royal Navy abandoned its tot of rum some years back in favor of a canteen system offering a ration of beer and other drinks at sea.

5 The United States forces overseas have Post Exchanges (PXs) which provide canteen goods, clothing and luxuries; and Commissaries, which are supermarkets, mainly devoted to food and drink, for families.

Part 2 Servicing

CHAPTER 10

Clean Servicing

The inside of a tank always has been a dirty environment. However high the standards of maintenance and discipline, the floor of an armored vehicle which has run several hundred kilometers since new is covered with a layer of grease, lubricating oil, hydraulic fluid, fuel, water, dust, mud, vegetable matter and crumbs and scraps of food. This viscous "bilgewater" is impossible to remove; it swills sluggishly around. I have seen crews spend hours cleaning and painting the clips of underfloor ammunition bins only to have them coated with dirt again the first time the tank takes a gradient or a corner. This dirt is a major cause of deterioration and unreliability in the vehicle, and the principal factor in debilitating minor ailments, mainly skin conditions, in the crew. Dust and dried mud which lodge in crevices above the bilges are an even greater menace to the reliability of internal subsystems. I cannot imagine this state of affairs being tolerated in any other setting in the services, industry or private life.

The liquid element comes mainly from leaks in inaccessible pipework, from spillages when refueling or topping up and from rain getting in through open hatches, grilles and louvers. The intakes of the NBC collective protection system are normally rainproofed in the same way as those of an automobile's heating or air conditioning system. But engine compartment louvers may not be; and the lid of an open hatch collects driving rain like a scoop. Now that the Germans have joined others in moving away from a hydraulic powered mounting, there seems no good reason to provide for any liquid except drinking water in the crew compartment. Hot hydraulic fluid under pressure is in any event almost as lethal to the crew as fire.

Vehicles with a snorkeling capability are normally designed with a "wet" engine compartment. This is allowed to flood down when the vehicle submerges, making it heavier and so improving track adhesion on the bottom. The technique also obviates the need for waterproofing the engine compartment. A wet engine compartment has to be separated by a liquid-tight bulkhead from the rest of the interior, so that any loose liquid in it stays there. Anyways, the engine compartment must be sealed off for collective NBC protection of the crew compartment; otherwise the agent or contamination sucked in with the aspirated engine air and cooling air swamps the system. Use of the engine compartment as an element in an integrated compound armor system, as in S Tank and the Israeli Merkava, reinforces this and related arguments. Finally, a wet engine compartment can be sluiced out with degreasing agents and detergents, and steam cleaned.

There is little technical problem about stopping rain getting in through the hatches. In conventional tanks the driver is normally shielded from above by the turret bustle or the gun mantlet. The driver's windshields provided on some vehicles are perfectly effective as long as they are not lost or carelessly broken - and are used! Top hatches can be protected in any one of three ways - by a screen and cowling like that fitted at the forward edge of many yacht cockpits; by a combination of windshield and hood rolling back to connect with the hatch lid; or by a button-on kayaklike screen drawn tight around the body. The problem is one of discipline - in fact, as we shall see in a shade later - of inculcating in tankers a whole new outlook about dirt.

If the engine compartment is isolated, solid matter comes into the crew compartment (and the rest of the armored envelope) in one of two ways. The more serious is dust taken in through open hatches when moving across dry terrain or even on dry roads. Desert dust is more plentiful and more destructive; but the dust thrown up by tracks from the battered terrain of training areas with sandy or other light soil is problem enough. The other path - normally for mud - is on the boots and clothing of the crew as they remount. This brings us to the nub of the matter.

With manual track adjustment and a habit of throwing its track on side slopes, Centurion was always producing scenes reminiscent of the obstetrics *viva* in Richard Gordon's *Doctor in the House*. I recall one occasion when a crew had been literally wallowing in mud to get a track back on. Just as the driver was finishing retightening the track, the complete adjusting mechanism came away. He rolled on his back in the mud, dragging the large spanner (the mechanism still clutched in its ring) down on top of him. When asked what had happened, he explained in a memorable sentence of six words, four of which were variants of the same expletive. The "wet wood on a dark night" replenishment scenario is not too different. Certainly it is dirty enough to make slippery mud on boots and gloves a real hazard as the crew climbs back onto the tank. Equally certainly, however careful the crew is, a lot of this mud is going to find its way inside with them.

Despite all these drawbacks and the resulting discomfort, resistance to change has come mainly from grassroots tankers. Aircrew are entirely ready to trust their ground crew, although a single mistake or oversight could cost them their lives. In my experience tank crew always have complete confidence in, and high respect for their organic or attached repair squads and even for forward repair teams or the like from supporting logistic units. Yet they do not like anybody else doing the basic servicing on their vehicle - or for that matter mechanical aids which make these very menial tasks quicker, easier and cleaner.

I imagine this attitude stems from the cavalry tradition of a trooper looking after his horse - something for which the arguments are unshakable. Certainly it represents a proud and basically sound armor tradition, backed by a considerable grain of truth. As a tank commander, I would be none too happy if my tank was going to be serviced by men outside my own subunit who had failed to make the grade as crewmen and/or by personnel from nontechnical logistic units. Evidently then five conditions have to be met if the crew are to be divorced from servicing without loss of confidence -

> Servicing operations must be controlled and supervised by somebody in whom the crew has confidence - in practice this means either a nonspecialist from their own subunit or a respected technical specialist organic or permanently attached to their own unit.

Servicing must be minimized.

As many servicing tasks as possible - in fact all checks - must be left in the hands of the crew but centralized so that the crew can carry them out without leaving their stations, either by separate manual procedures or by running a checkout program on the on-board computer.

The crew must be able to monitor replenishment procedures from their stations, either visually or by suitable devices.

For emergency repairs (such as a track thrown or cut by a mine) the crew must have support from men in their own subunit who can dismount even in NBC contamination without disastrous consequences for their vehicle - such as the maneuver squad of a composite platoon.

We will look fully at replenishment in later chapters. For the moment I want to address the broad implications on design of satisfying these conditions.

The first point of attack has to be track maintenance. The main breakthrough here, the **automatic track tensioner**, was made several decades back and is now, I guess, universal except in the most masochistic or ill-equipped of armies. The goal is, though, to eliminate all track maintenance except that caused by battle damage or tied into major scheduled maintenance. So we need first to minimize the risk of track throwing in ruts or on any side slope which will not overturn the vehicle. Since the avoidance of track throwing depends largely on maintaining the correct tension, an automatic tensioner helps a lot. But if the horns of the track links (fig 5) are not shaped to lead the track into line or are not deep enough, throwing can occur even with a deliberately overtightened track. By the same token mud must be prevented from packing in the groove between the roadwheel tires into which the horn fits, or between overlapping roadwheels. Since vertical roadwheel movement is too great for scrapers attached to the hull to be effective, the wheel must be so designed that mud is shed towards the center of the wheel and thrown clear by the hub. The Soviet "open" design of roadwheel looks to have much to commend it here.

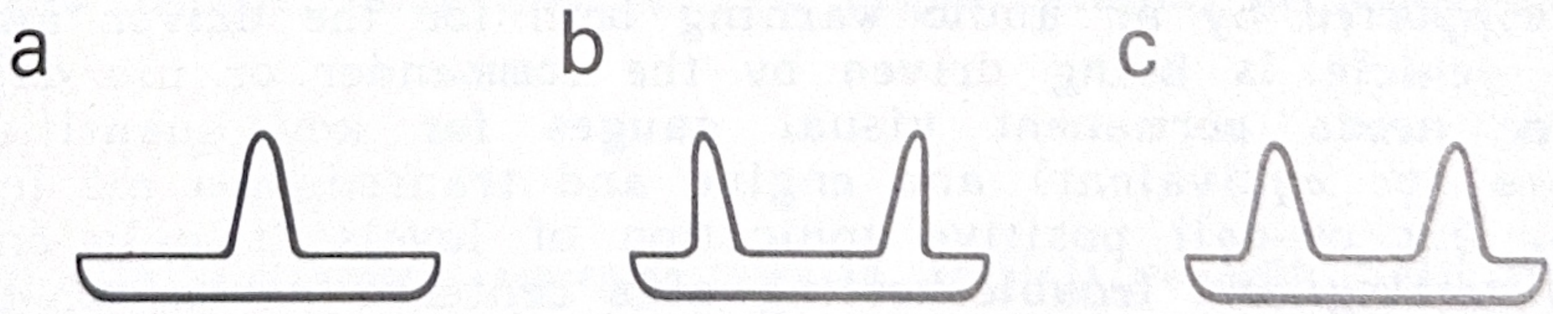

Figure 5. Schematic of track link

a. Twin-tired roadwheel b. Single wide-tired roadwheel
c. Staggered roadwheels (e.g. Panther).

In each case, the profile of the horn(s) must be such as to lead the track back into line whenever its/their tip(s) lie(s) within the periphery of the roadwheel.

Causes of track throwing which are less obvious but may be more important for the future are **suspension characteristics** and **track dynamics.** My own experience (1) suggests that even a fully tightened track at low speed is liable to come off on quite a mild side slope if the horns become disengaged from the grooves of 3 consecutive roadwheels (out of 5 or 6). Future high mobility running gears are likely to have vertical roadwheel movement approaching 1 m. A combination of high speed, this kind of amplitude and a rather low suspension frequency could well allow a track to shed itself in a combination of bump and rut without a lateral gradient as such.

Then again, a track (considered as an endless belt) cycling at the angular velocity equivalent to a vehicle speed of, say, 90 kph, will develop considerable centrifugal forces. These will tend to shape it into a smooth loop and to hold it off the wheels guiding and/or carrying it. Third, designers of these high mobility vehicles will strive to keep track weight (as part of the unsprung weight) down. Both this and other technical requirements, combined with reduced vehicle weight, will tend to result in a track that is much more pliable and subject to twist than those of today. Unless very deliberate action is taken to prevent it, we may well be moving into another era of track throwing (2). This is just not acceptable in a defensive battle under threat or actuality of NBC contamination. My own guess is that we shall reach a point at which the need for a smooth ride without losing the track will set a limit to usable cross-country speed for anything resembling a conventional tracked running gear (3).

A second technical aspect which ties in well with the kind of vehicle configuration on which this book is based and with the trend towards integrated compound armor systems (4) is the need to group **fillers.** It is reasonable to suppose - and certainly acceptable for the future - that the engine hatches will be a crane lift. In this event all fillers would need to be grouped at a central point within easy reach of two crew stations (fig 1, page 20), just behind and protected by the top edge of the sloped upper front (with the sealed bulkhead shaped to run aft of them). In this event any crew member could visually monitor all refilling operations without opening up. Alternatively, given suitable dispensing nozzles, the crew could themselves fill up with all fluids needed without dismounting or even completely leaving their stations. One might envision this filler area being covered by a hinged plate with a pocket for protective gloves on its inside lid.

The remoting of filler caps calls for **positive remote indication of levels.** Presumably future armored vehicles will conform to aircraft and automobile practice in having a comprehensive system of warning lights in the driver's station, supported by an audio warning both for the driver and for occasions when the vehicle is being driven by the commander or his deputy. Evidently the driver needs permanent visual gauges for key quantities like coolant temperature (or equivalent) and engine and transmission oil temperatures and pressures. But on-call positive indication of levels is only one element in a system of **testing and troubleshooting aids** centered on the on-board computer. We already discussed (page 32) the rather extensive test programs desirable when lying up in hides. For both technological and psychological reasons, these should probably cover all aspects of daily and weekly servicing, testing and subsystem exercising. There is also a need for a quick program equivalating to daily and prereplenishment checkouts. One part of this could be used on its own to give the vehicle commander the replenishment requirements -

> ammunition (see below), fuel, water, coolant, engine oil, transmission oil, hydraulic fluid (by subsystems), and any other similar commodity the design may require.

The functions the other part of the program might test are (typically but not exhaustively) these -

tracks - tensioner functioning, residual stretch (before removal of a link)

dry brakes - state of pads/linings

extinguishers - detectors, state of charge of units

batteries - electrolyte level and state of charge

powered mounting/stabilizer functions

fire control functions

vision/acquisition sensors

autoloader

communications system

Finally, as a third part of this program or separately, the computer must be able to monitor its own functioning.

With magazines of the type used in S Tank or M1 Abrams, the crew commander will require aids to check his ammunition state. If these magazines are exchanged by mechanical handling on replenishment, he will also need to be sure that he receives a full one and not a part-used one which may contain less ammunition than the one withdrawn from him. Thus it is not enough to count rounds expended. There must be a positive indication by type of main armament rounds held. Additionally the commander must be able to check remotely that secondary armament ammunition and any other commodities supplied with the magazine are present. All this means a multicircuit connection between the magazine and its supports. Careful design of the interface is needed to ensure that this connection is properly made when the magazine is inserted mechanically - doubly so since the connector may have to carry power circuits for actuation as well as control and test circuits.

Finally on the technical side there is one key point of a rather different nature - adding up in fact to a reversal of the trends we have been discussing although it derives from them. In the next chapter we shall look at the need for crew repair, and then at the organizational implications of this whole discussion.

Notes

1 Notably with handling and recovering tanks in the hills and paddy fields of Hong Kong's New Territories.

2 As one gathers the Soviets have with T64 (See Bibliography, Suvorov).

3 Reduction of the unwanted dynamic effects is to my mind one of the more interesting features of the Swedish articulated concept (e.g. pl 5).

4 In which the power train and its ancillaries and supplies form part of the frontal armor (cf. S Tank, Merkava).

CHAPTER 11

Crew Repair and On-the-spot Support

We saw the importance of keeping the crew **inside** their vehicle in a contaminated environment, or even just a muddy or dusty one. This requirement marches with parallel trends to reduce the crew's servicing tasks or at least to take the physical effort out of them. Evidently it is just as important to minimize the need for anybody else to get **into** the clean, NBC-protected part of the vehicle. Repair specialists carry just as much mud and/or contamination on them as lesser mortals. We already accepted the likelihood that the engine hatches would be a crane lift and that in situ repair might lead to a contaminated engine compartment, divided from the rest of the vehicle by a sealed bulkhead (1).

The other side of this coin is the need for the crew to carry out nonscheduled maintenance within the protected volume. This adds up to unit replacement; but in our electronic era it is easy to forget that armored vehicles and other complex systems still contain a fair proportion of mechanical, electromechanical and hydraulic assemblies which are apt to go wrong. Then again there is the problem of diagnosis; computerized troubleshooting, like unit replacement, is much easier to apply to electronic-based subsystems than to mechanical or hydraulic ones. So the problem of repairs within the clean area calls for **a consistent philosophy embracing distribution of duties, repair techniques, diagnosis, spares scaling and distribution, and above all detailed subsystem design.**

My personal and vicarious experience with the assisted loading arrangements in Conqueror and of early proposals for Chieftain are things I prefer to forget. Tales going the rounds about T64's autoloader actually eating a few of the Soviet Army's minicrewmen provide further indication of autoloaders' susceptibility to temperament. **Autoloader** failure may put future armored weapon platforms out of action; certainly it will reduce their firepower to a point where their contribution to the battle and their chance of survival are equally slender. Yet the inevitable size of key components and assemblies virtually rules out significant redundancy. So the autoloader merits quite special attention.

In any feed or conveyor system of this kind there is usually one location or function which is the major cause of jams and stoppages. In fact it makes good design sense to concentrate mechanical awkwardness and/or sensitivity of adjustment in one stage of the cycle. It should then be possible to provide the crew with an emergency lever or whatever which will clear this particular

snafu, if necessary by disposing of an unfired round through the ejection port (or a special port). This apart, repair of the kind of thing that is likely to go wrong with the kind of mechanism the autoloader has to be will probably lie well beyond any reasonable crew skills. So the autoloader must be accessible from outside. This requirement marches well with the isolation of ammunition from the main armored envelope (to reduce fire risk); a first glance suggests that, with magazine(s) withdrawn, it should be feasible on fixed gun, external gun and turreted configurations alike (2).

Cannon and machinegun loading and stoppage clearance would be dealt with manually from inside in the normal way. If the IFV/CSV also carries a low pressure 76 mm gun, limited autoloading would be catered for by a simple clip arrangement. Again replacement of clips and any problems that arose could be dealt with manually from the rear compartment.

The importance and predictable unreliability of the autoloader make it a special case. Maybe one day it will qualify to join other subsystems and components which, under NBC threat, can only be dealt with by specialists working in a protected environment. Fortunately most of these subsystems are highly reliable unless battle damage occurs within the armored envelope. One or more of three factors may qualify items for this category -

inaccessibility without major stripping

size and/or weight

dangerous permanent spring and/or hydraulic pressures

I have in mind such things as these -

wiring harnesses (and piping, if any)

slipring connections between hull and turret (or the equivalent)

main armament recoil system and breech (excluding firing mechanism)

major mechanical components of mounting (e.g. elevation arc)

Evidently the makeup of the list will vary with configuration and subsystem design, but these examples will serve. The requirement, normally attainable without too much difficulty, is for optimum reliability and long intervals between scheduled maintenance.

Since the principles of remote troubleshooting and unit replacement are so familiar in the **electronic field**, we might explore this side first and then look at the extension of this approach to other types of system. As always seems to be the case with armored vehicles, there are interlocks and conflicts between the aspects of diagnosis and replacement; so we need to consider them together. The limiting factor is the set of physical constraints concerned with replacement. Units must be small enough to pass through the hatches and any other awkward constrictions. They must be light and handy enough for one man to withdraw them into the hatch from possibly contaminated packaging held by a man outside (and to pass out defective units in the same way), and to withdraw them from/insert them into their mountings.

Even with microminiaturization, small units making up a large number of complex subsystems add up to a lot of packs. So the function of each pack will be limited. I have already underlined the need to make maximum use of the

on-board computer and its peripherals for training, testing, exercising crew and subsystems, and entertainment. But its power will in fact be governed by its fire control task. This should more than match the needs of routine checkouts but may be inadequate for pinpoint diagnosis. Likewise the diagnostic program will be complex; it would take a significant time to put in, and the crew might well have problems interpreting the outputs.

I would therefore see troubleshooting as a two-stage process. The crew with the on-board computer and its normal test programs should be able to identify the faulty subsystem and either the nature of the malfunction or the part of the system affected. The repair specialist can receive this information by radio and work out from it what detailed diagnostic programs and spare units he will require. From the need to remote certain facilities when the crew or squad are dismounted, we already envisioned a connector panel back of one of the external stowage bins. Likewise there is a need for a connector to link the diagnostic computer on the repair squad vehicle to the on-board system in its diagnostic mode. This supplementary program and computing power would allow the defective pack to be pinpointed.

This leaves over an important problem analogous to the one I raised just now in the context of changing magazines. No specialist will be available to connect up the new unit. If possible disconnection and connection should be automatic on withdrawal and insertion of the unit, but the need for a resilient mounting may make this insufficiently positive. If connections have to be made manually by the crew, much thought must be given to the design of connectors. The kind of multipin connector used in commercial audiovisual equipment and sixties and seventies military radio installations is just not acceptable. I have seen even simple examples of these connectors damaged by a technician sitting at a workbench. The chance of an awkwardly placed pack being correctly connected up by a tired and frightened crewman is rather low. Being notably clumsy myself, I believe the clue is to provide positive self-centralizing mating between the bodies of the male and female connectors, so that the contacts themselves are precisely and correctly aligned before they touch each other.

The clean crew compartment contains two broad categories of **mechanical and electromechanical** assemblies - control units and subsystem drive motors. From the viewpoint of replacement by the crew, units with electrical inputs and outputs (such as a motor/crossfield generator group) can be treated in the same way as electronic packs. The distinguishing features of the assemblies we are now discussing are that their location is determined by their function, and that they will usually have mechanical and/or hydraulic connections. There are maybe four angles on the problem - design of unit, design of connectors, instructions and tools.

The first goal is to minimize the number of such units by grouping them, subject evidently to limits of size and weight. Thus, although far more complex, a joystick-type driver's control assembly (as in S Tank) is going to present far fewer problems from the replacement point of view than the conventional driving controls of a tracked vehicle - pedals, steering levers and parking brake. Joystick control is entirely adequate for driving, essentially a two-dimensional function. But a good deal of evidence from the aircraft, armored vehicle and guided missile fields suggests that training is simplified and control made more precise if one plane - normally azimuth - is separated out (3). I would in fact see only 7 manual control units with progressive control functions (as opposed to flip-flop controls like switches) in a future armored vehicle - a primary driving control unit in the driver's station; and in each of the other identical stations: a secondary driving unit to the right hand and a traversing controller which rocks for elevation, also incorporating the firing switch, to the left (4).

If the interface between the control unit and the rest of the subsystem is electrical or electronic, the problem about connectors is identical with that discussed above. The location of control assemblies and the nature of the subsystems they govern make mechanical connections unlikely. There is however a high probability that high-pressure hydraulic lines will be involved. It is tempting to suggest interposing an electrical or electronic link interfaced with the control assembly so that the hydraulic connections can be made at a location assessible to specialists, from the engine compartment or elsewhere outside the clean part of the armored envelope. But quite apart from the statistically predictable impairment of reliability, experience suggests that this solution may impair precision or instantaneity of response. Future gunnery subsystems are unlikely to be hydraulic except for the elevation system of the fixed gun tank; and there the change from electrical/electronic to hydraulic is downstream of the computer.

So the problem is effectively confined to driving control units. Grouped hydraulic connectors are inherently risky because the person making the connections has no means of checking that each individual connector has mated correctly. So one is back to individual connectors. Threaded unions invite crossing threads, overtightening and/or twisting of the pipe. Bayonet connectors are fine for low pressure, as are small-diameter interrupted threads. But for high pressures two-stage fittings seem necessary, with the locking stage probably being provided by a toggle or similar overcenter mechanism.

Drive motors, say for elevation or traverse of the weapon pod, present a far more serious problem because **the output has to be mechanical** and the drive pinion must mate with the toothed arc or ring (or intermediate gear train) correctly and without backlash. Additionally the rotational datum positions of the driving and driven members may be significant. From experience I am inclined to think that the conventional split, in which the pinion is grouped with the motor, is bad from the viewpoint of replacement by the crew. The most foolproof split is probably between male and female splines, with a master spline if needs be. This arrangement also makes the axial position of the replacement unit - in fact the evenness and force of tightening - less critical; though I would still think a torque-wrench would be necessary to achieve axial alignment.

This brings us to the external aspects of instructions and tools. The standard set by the armed forces in preparing instructions of this kind is a clear league or two above commercial practice. Even so, being written by a specialist who could carry out the whole procedure blindfold with his hands tied behind his back, these instructions sometimes group too many actions together; and/or they fail to explain, or even omit some simple and glaringly obvious but nonetheless essential step - such as the easy way to assemble a bolt through a.base-plated fitting onto a washer and nut.

One key point for repair work done by the crew inside an armored vehicle is that the instructions should be clear when read aloud by a person who does not fully understand what is going on. Quite simply the man carrying out the changeover may be in no position to read the instructions; and the man reading them may be unable to see what is happening. An audio or even video tape might be valuable for preliminary briefing. But an audio tape for use during the procedure has two drawbacks - the man doing the work has no hand free to stop and restart it (5); and this fact, combined with the pace of the tape, may pressure him into rushing the job.

In peacetime, soldiers armed with paintpots and brushes are probably the greatest single cause of damage to complex equipment. Much the same goes for

tools; a general-purpose toolkit is an invitation for the crew to misapply it. I can see little greater across-the-board need for tools to be carried on future armored vehicles than on aircraft or modern automobiles. Many slacking off and tightening requirements can be catered for by permanently fitted knobs. Keys, wrenches and screwdrivers or the like can be designed for a single purpose and kept captive in the area they are needed. This approach should cover routine adjustments, tests and servicing, likewise the replacement of electronic packs (which can be physically identical whatever their function). Tools for electromechanical and mechanical unit replacement should come up with the replacement unit and go back with the defective one, forming a part of the pack like the instructions and any other aids. These tools should be key-lettered (to the instructions) and again as far as possible single-purpose. Torque wrenches or drivers should be designed for a fixed torque or preset and sealed.

As I have probed deeper and deeper into the nitty gritty of crew repair, the reader may have felt that I was envisioning a crew of morons who would be quite incapable of fighting their vehicle. Not so - and it behoves us at this point to clear up some loose thinking that is apt to go on in selection and training organizations. **Manual skills** based mainly on the trained application of physical effort are of diminishing importance in a mechanized force. The need for them is probably now covered well enough by basic medical standards and the high level of general fitness required of soldiers.

Driving and gunnery procedures are mainly **single-skill control tasks** - that is, only one particular skill at a time is required, and the selection of the relevant skill is either ordered, or dictated by circumstances. If however the commander's and gunner's (or deputy commander's) facilities and roles are to be largely duplicated - as we shall see they must be - both these crewmen need to be capable of **multiskill control tasks with a short-term judgmental element.** The proportion of the population - let alone of the recruitment base - capable of such tasks is limited; and this set of aptitudes has little correlation with those called for in the skilled craftsman, which are likewise limited in availability. Aiming at a combination of both sets of aptitudes in one man brings a further quantum jump backwards in availability.

This is why I have laid such stress on automating and/or simplifying crew servicing and repair tasks. Thanks to the ease with which routine testing can be automated, armored vehicles do not yet call for the complete split into air and ground crew which has long typified air forces. By contrast, certain nonscheduled maintenance tasks may have to be carried out by the crew. But high manual skills should not be a constraint on crew selection. By the same token crews have to be fully trained in the use of their aids for routine monitoring and servicing. But there is no point in cluttering their training with instruction on repair procedures which they may carry out once in their service if at all.

This is evidently a situation in which pride of place must go to the correct selection and training of human resources for their primary role. Supplementary tasks need to be tailored to the relevant abilities of the crewmen produced by this selection and training process.

Following this rationale through, we can now turn to the organizational aspects of the support the crews of armored vehicle weapon platforms require. Operation of the vehicle and command and control add up to a different

ballgame which we shall analyze in Part 3. Here we are concerned with support of four types -

regular physical assistance with replenishment

physical assistance with nonscheduled maintenance, e.g. repairing a track cut by a mine

specialist advice to crews carrying out nonscheduled maintenance

specialist execution of nonscheduled maintenance, e.g. repairs to power train, pinpoint diagnosis of an electronic fault

There are two factors which will tend to increase the extent and urgency of this support in the future. One arising from the NBC threat we already probed in depth. The crew may be unable to dismount, or specialists to enter the crew compartment without risk of contaminating the clean area of the vehicle. The other factor lies mainly outside the scope of this book but impinges at this point. It is the tempo of the battle, which requires as much of this support as possible to be available on the spot.

This is one of the main reasons why, in everything I have written, I have consistently and strongly favored the composite (tank-infantry) unit integrated down to the level of a large platoon. Maneuver squads provide the manpower needed for regular and emergency physical assistance both to their own crews and to those of the associated weapon platforms. A platoon large enough to justify a headquarters section (6) containing a command and support vehicle (CSV) greatly extends the help available on the spot.

The CSV's most important **support** task is probably the immediate recovery of battle-damaged vehicles, unhorsed crews or battle casualties. I stipulated elsewhere that, in addition to its crew of 3, plus 2 spare crewmen doubling as relief signalers, the platoon CSV should carry a medical orderly and "survival kits" for crew and vehicles as a first backup to the on-board stores. This vehicle could easily carry one more man. I am now inclined to think that it should, and that he should be an electromechanical specialist tradesman. In the same sense, there looks to be a need for a winch (which I had tacitly assumed) and a derrick capable of lifting an engine hatch and raising and lowering a magazine during emergency manual removal and replacement. I have autoloader problems partially in mind here. I reckon it should be feasible for the CSV to carry this derrick in a collapsed form without its becoming visually distinguishable from the squad IFV.

By contrast support for electronic repairs must come from outside the platoon because it calls for a vehicle carrying special diagnostic facilities and a wide range of spares. Since vehicles with electronic defects are usually mobile, they will be able to pull out of the battle and probably to move to the repair squad location.

This has necessarily been rather a detailed and piecemeal chapter, so let me conclude by driving home the key general point it demonstrates. Personnel selection and training and force structure are as closely bound up with **detailed** design as operational concepts - and of course force structure again - are with the general design and configuration of armored vehicles.

Notes

1 Inevitably the repair squad's vehicle, like the IFV it derives from, has to be of the "dirty rear compartment" type.

2 Though not, from what I know of it, in the Soviet arrangement, where the main magazine appears to be under the fighting and engine compartment floors.

3 Conversely the helicopter case, in which - until very recently -two separate controls ("collective" and cyclic pitch) had to be operated in conjunction for a single function, presents extreme training problems.

4 Not the same motion as a joystick. See also Chapter 18.

5 I appreciate this can now be done by an oral command, but I feel this would amount to oversophistication in this context.

6 This large platoon calls for **two** lower levels of group which (after some dithering) I designated section and (mounted) crew/(dismounted) squad.

CHAPTER 12

Replenishment Techniques

Running gear repairs in the field can indeed be a messy business, but the steady influx of dirt into the tank, the uptake of noxious substances like diesel fuel by the crew's skin and clothing, and minor injuries leading to debilitating skin conditions mostly stem from replenishment. A leading speaker at the 1979 United States Army Armor Conference observed that the approach to packaging and handling tank ammunition had remained virtually unchanged for almost fifty years. Holding a senior logistics appointment at the time, he took the bulk of criticism for this on the logisticians' shoulders; but in fact much of the blame rests with conservatism among tankers too. I well recall the struggle I had in the fifties to get first-line 20 pounder (later 105 mm) ammunition in British Army of the Rhine carried in racked trucks instead of boxes. Sure, there were a few technical problems; but the biggest difficulty by far was emotional resistance from tank battalions and logistic units alike. It was only the increase (as I recall around 40 %) in the number of rounds carried in available unit trucks that finally brought the higher armor commanders round and made the idea stick.

Scarcely easier to understand was the long rearguard action fought by tankers in both the British and United States Armies against bulk refueling. This resistance had some justification in fact. With racked ammunition trucks and dedicated refuelers much of the flexibility of unit holdings was lost, although the increase in the amount of commodity carried per ton of nominal payload was, in both cases, so substantial as to outweigh this. Then again, the adapted commercial equipment initially wished on British Army of the Rhine and (as I recall) on 7 (US) Army might have been designed to stifle the project at birth. Tank design did not much encourage innovation either. The rate at which the fillers on Centurion, for instance, could accept gasoline was based on the single jerrican and funnel. Even the "jerrican hoppers" later introduced could produce enough flow to defeat the left hand fuel tank. Likewise bombing up round by agonizing round through the top hatches and/or a special ammunition port was a bottleneck that cost crews hours of sleep - and tactical commanders hours of lost availability. Under ideal conditions (again based on recall) it took an arm school crew around 3 hours to bomb up Centurion completely; M60 was not too different.

Now that the bulk refueling is accepted and there are two tanks in service with externally vented magazines (S Tank and M1 Abrams) the scene is set for a revolution in replenishment techniques and procedures. There is something of a chicken-and-egg problem here, though. **Replenishment in lager** - the "muddy

forest ride on a dark wet night" scenario that is every tanker's nightmare - is a slow and dirty business whatever the aids. But given good noise discipline this procedure is fairly unlikely to be detected from the ground; and even with modern sensors, detection and attack from the air are unlikely if good natural cover is available. Likewise a unit can be replenished in this way while maintaining whatever counternuclear dispersion is laid down (1).

The alternative procedure, **running replenishment** (or "rolling replenishment") really adds up to the setting up of a mobile service station along the route or at the entrance to a lager or hide area. Armored vehicles roll in, replenish from each commodity point in turn, and move on. Being almost impossible to conceal, running replenishment entails a significant tactical risk, specially in an adverse air situation. Safety lies in speed. But speed requires dedicated supply vehicles and direct interfacing of supplier and supplied. Optimization along these lines can virtually put an end to conventional in-lager replenishment.

As long as tanks had to be bombed up manually round by round, in-lager replenishment remained an essential option. With the possibility of exchanging magazines, there is almost certainly a payoff in optimizing on running replenishment and treating in-lager replenishment as an isolated emergency to be catered for by small reserves carried in the company service platoon. I examined some of the basic procedures in *Antitank* (2); here I should like to develop these ideas from the viewpoints of crew wellbeing and the distribution of duties. Because the IFV and its CSV and other variants will still have to be bombed up manually, maneuver squads and the spare men on command vehicles may be mostly required for replenishing their own vehicles. They may also be called on for local defense; so in this instance they cannot be regarded as a manpower pool.

Because it is common to all vehicles and the techniques required are well-established, we might consider **refueling** first, linking it to other "**technical fluids**" (lubricating oils, hydraulic fluid and the like, maybe liquid and/or gaseous nitrogen) but **not** to water. There is a strong pull between, on the one hand, the number of vehicles one tanker truck can replenish (with complete refills) and the effective use of drivers; and on the other the amount of fuel at "one-shot" risk and the supply vehicle's off-road mobility. Evidently a move towards smaller and less thirsty armored vehicles would ease this conflict.

The supply vehicle's optimum capacity is linked both to combat unit organization and to replenishment procedure. We shall look at these aspects in the next chapter; for the moment I am going to assume a capacity sufficient to refill 8 armored vehicles completely. Second, to streamline replenishment procedure, fuel capacity as such needs to be traded off in two directions. The tanker (fig 6) must have a pump unit capable of maintaining at each nozzle simultaneously a flow rate equal to the maximum the armored vehicle's fillers can accept. Additionally the refueler must carry a "service station" type pressurized dispensing and metering unit catering for all "technical liquids" needed, with capacities matched to the forecast average requirement of each and the number of vehicles which can be refueled.

The refueler should be able to serve two vehicles at once, either one to each side or one behind the other, without anybody setting foot on the ground (see also page 93 and fig 11). To deal with replenishment in contaminated areas or of contaminated vehicles, the tank truck needs a driver and a codriver. The codriver will also be required to help refill the truck with its secondary

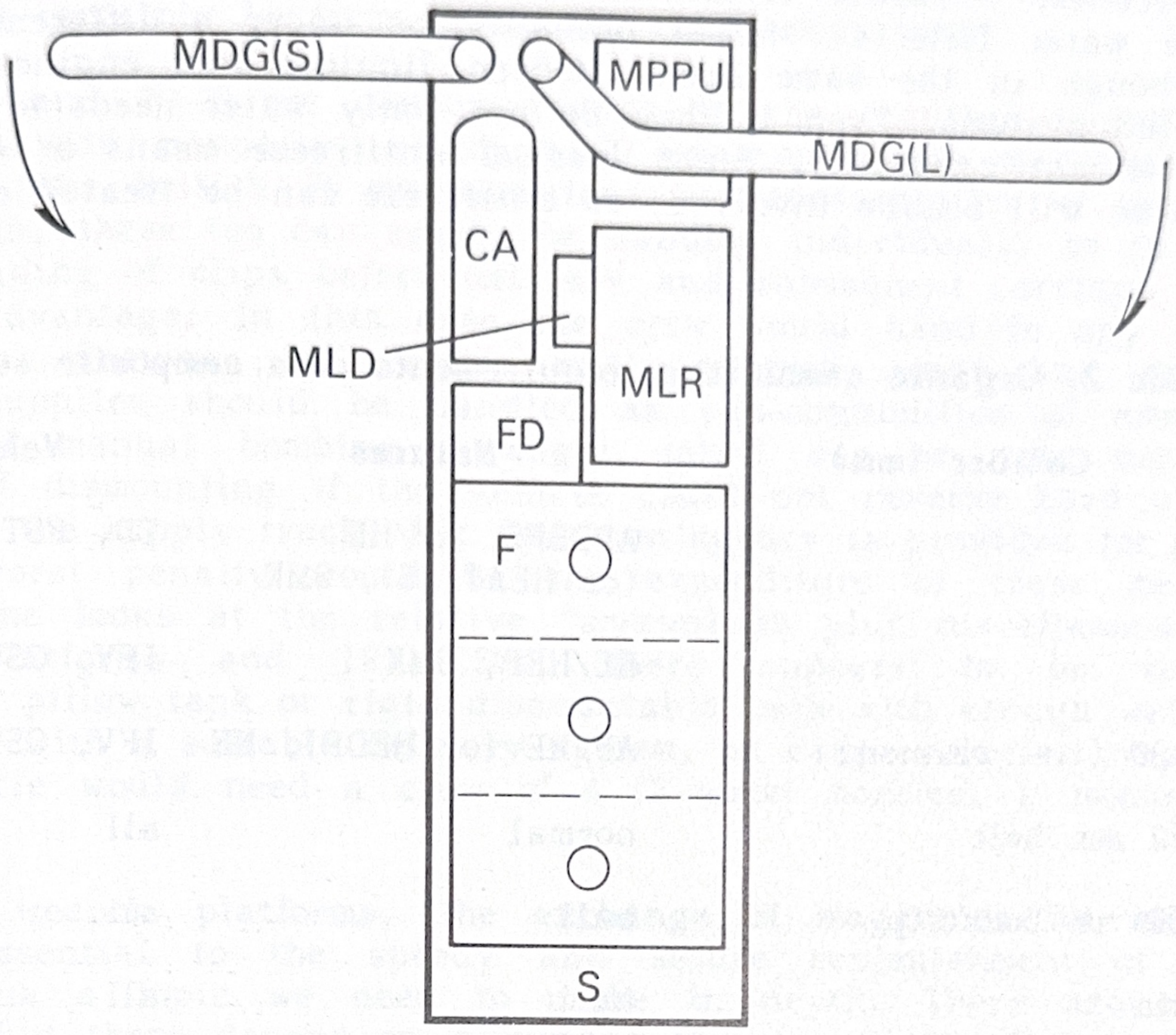

Figure 6. Tanker/servicing body - schematic

Envisioned as swop body, 6 m x 2 m platform, horizontal longitudinal loading. CA = control area (raised platform over pipe galleries), F = fuel tank (7000 l); FD = fuel delivery valves etc; MDG(L) = multi-delivery gantry, long, above MDG(S), swings parallel to left hand side of vehicle for stowage, and to rear left for alternative replenishment positions; MDG(S) = multi-delivery gantry, short, lower than MDG(L), swings slightly forward of position shown for refueling/servicing 2 vehicles on same side, and rearward parallel with left hand side of vehicle, under MDG(L), for stowage; MLD = multiliquid metering/delivery arrangements; MLR = multiliquid reservoirs; MPPU = motor/fuel pump/hydraulic pump unit (also supplies control electrics 24 v DC stabilized).

commodities at the crossloading point, and as a relief driver to ensure full utilization of the vehicle over long periods.

Two swiveling gantry arms should be mounted at the left rear of the cab. When not in use they would lie along the side of the main (fuel) tank. The shorter of these gantries should swing out square over a group of fillers in line with the rear of the cab on the (truck) driver's side; the longer should reach the fillers of an armored vehicle halted either by the other side of the cab or ahead of the "short reach" vehicle. Each gantry would carry a nozzle for each commodity provided. The fuel nozzle would be distinguishable by size and shape and would have the normal squeeze grip with a lock-on device and automatic shut-off. For working in the dark, the oil/fluid dispenser nozzles should have heads of distinctive shapes mating with filler apertures of similar shape. Likewise one actuation of the trigger on the dispenser head should deliver a predetermined quantity. With this arrangement, which closely resembles that of a number of commercial servicing trucks and portable units one man should easily be able to replenish all subsystems within the time it takes to refill the fuel tanks.

Water should ideally be replenished at the same time as ammunition, **not** fuel and lubricants, in order to minimize the risk of a disastrous mixup. In any event the water filler(s) should probably be under a different flap from the rest, although in the same area. Modern liquid-cooled engines are likely to have sealed systems. Even if they do not, only water needs to be supplied as a replenishment commodity. Since loss of antifreeze means a leak, the repair organization will become involved; so antifreeze can be treated as a "spare."

Table 2. **Organic ammunition requirements of a composite subunit**

Caliber (mm)	Natures	Vehicles
105	APDSFS, AP/HE (or HEAT/FS), SMK	TD, FST
76	HE/HEP, SMK	IFV, CSV
20-30 (i.e. cannon)	AP/HE (or HEDP), HE	IFV, CSV
7.62 mm belt	normal	all
7.62 mm box/clip	ball	all
9 mm	ball	all
Manportable/crew served antiarmor systems		
ATGMS	1 nature	(some) IFVs
Rockets	1 nature	IFV
Antitank grenades	1 nature	IFV (plus)
Limpet mines	1 nature	IFV (plus)
Grenades (* = plus cartridges)		
Anti-ATGM*	(1 nature)	TD, FST, IFV, CSV
SMK*	(conventional cups)	all
Hand	HE/FRAG	all
Flares		
Cartridges signal/ illuminating	various, at least 4 types	all

Ammunition resupply is a far more complex problem (Table 2). As I argued in *Antitank*, the primary weapon platforms, the tank destroyer (TD) and fire support tank (FST), present quite a different problem than the IFV, CSV and secondary members of the family. For the second group no change from manual

handling seems feasible or even desirable. Although one hopes the magazines and ammunition stowage of these vehicles will be externally vented, access to them will almost certainly be from within the rear compartment.

Belted 7.62 mm and 20-25 mm cannon rounds in the required quantities can easily be dealt with manually, although 30 mm rounds are marginal in this respect. If we take British 76 mm munitions as representative of those for a low-pressure gun, these too can easily be handled individually or in clips of up to 5. Preloading of clips before delivery and subsequent carriage in racks would be an advantage; in this case the crew would hand in any empty or part-used clips. Rations, NBC suits, mail, canteen goods and any other miscellaneous supplies should be handled as sub-commodities of ammunition. This traditional manual bombing-up might entail one or more men of the maneuver squad dismounting if the vehicle could not reverse hard up to the side or rear of the supply truck. But this contingency is provided for (Chapter 6) and the worst penalty would be the expenditure of these men's NBC oversuits. If one looks at the relative "ammunition plus miscellaneous" loads for weapon platforms and IFVs/CSVs, there appears to be scope for incorporating a pillow tank or rigid dismountable tank with enough water for 8 vehicles, along with a suitable delivery system, on cargo vehicles used in this role. The vehicle would need a crew of 4 (2 water nozzles, 1 ammunition, 1 miscellaneous).

For the main weapon platforms, the **exchange of magazines by mechanical handling** is essential to the speedy and secure replenishment of armored units - and thus a topic we need to probe in depth. There are two main aspects to it, but these depend on a number of assumptions. One is that this exchange of magazines offers the sole opportunity of transferring large solid objects between armored vehicle and supply truck without risk of contamination when either vehicle is externally contaminated or replenishment takes place in a contaminated area. (Special deliveries like mail are an evident exception; these would have to be delivered in the same kind of way as spares (see page 71.) Then again, design trends in East and West alike suggest that M1 Abrams with its turret bustle magazines is the exception. Whatever the armored vehicle's configuration - and whether or not this requires a "ready-round" magazine on the gun mounting - the main magazines are going to be located at the rear of the hull, with the lie of rounds and the axis of magazine exchange parallel to the longitudinal axis of the vehicle.

In S Tank, M1 Abrams and seemingly T72/T80 (3) a third type of round (most likely smoke in the first two cases and HEATFS in the third) can be loaded manually. In future layouts this may well be impossible, the only manual intervention in loading of the main armament being clearance of a stoppage (page 70). Thus the magazine arrangement (likewise the autoloader) must provide for a small quantity of a third nature. Use of an autoloader removes the restriction on the heaviest single item which can be manually loaded by one man (4). So even 125 mm ammunition can be of the "fixed" type; length is critical only if the magazine and loading system turns the round between horizontal and vertical (as seemingly in T72). Last but not least, the design must provide for round-by-round manual recharging of the magazine(s) from outside the vehicle as an emergency expedient.

Given these premises it may be best to look first at the more complex but less challenging aspect of the problem - the arrangement of the magazine(s). For simplicity in discussion, I shall assume a total main armament ammunition stowage of 50, normally split 20/20/10 between two main types and a secondary type. To ensure flexibility, each element of the magazine must accept any type of round. It then becomes feasible to load 30/20 or even 40/10. Likewise the magazines for the TD and FST must be physically identical, though they may

be differently loaded to match the tactical situation. The tactical commander would order the appropriate filling of magazines at the point (presumably the divisional train) at which bulk was broken and the magazines were normally recharged and prepared for delivery - more of this in a moment.

Additionally, in a position accessible to the crew through a flap in the bulkhead between crew compartment and magazine, there must be a compartment for a standard load of all types of secondary ammunition along with rations. Since this secondary ammunition needs to be immediately available and represents a relatively low fire risk, a limited quantity would have to be stowed in ready positions inside the crew compartment (5); these would be topped up as required from the magazine. This "secondary" compartment of the magazine needs its own NBC-proof lid, mated with the access flap when the magazine is in position in such a way as to prevent transfer of external contamination to the crew compartment.

There is a case for separating the magazine into 2, 3 or even 6 modules (fig 7). This rests partly on the flexibility argument but mainly perhaps on the weight and size of the magazine as a complete unit. On ballpark figuring with rather generous allowances for structure and add-ons (6), this unit would weigh about 2250 kg for standard 105 mm munitions. (Extrapolating directly from this, a MLC40 vehicle could carry only some 30 125 mm rounds in this way, an MLC60 vehicle around 45; but there are a number of compensating factors (7)). So we are looking at a unit around 2 m (at most) wide, 1.5 m high and 1 m long, weighing 2250 kg. On the 6-module option (5 x 10 x 105 mm, 1 secondary) each module would measure around 1 m long x 0.75 m wide x 0.5 m high and weigh rather over 375 kg. These would be much easier to handle but they are still too heavy to manhandle as a normal procedure; so 6 transfer operations, each needing separate alignment, would be involved.

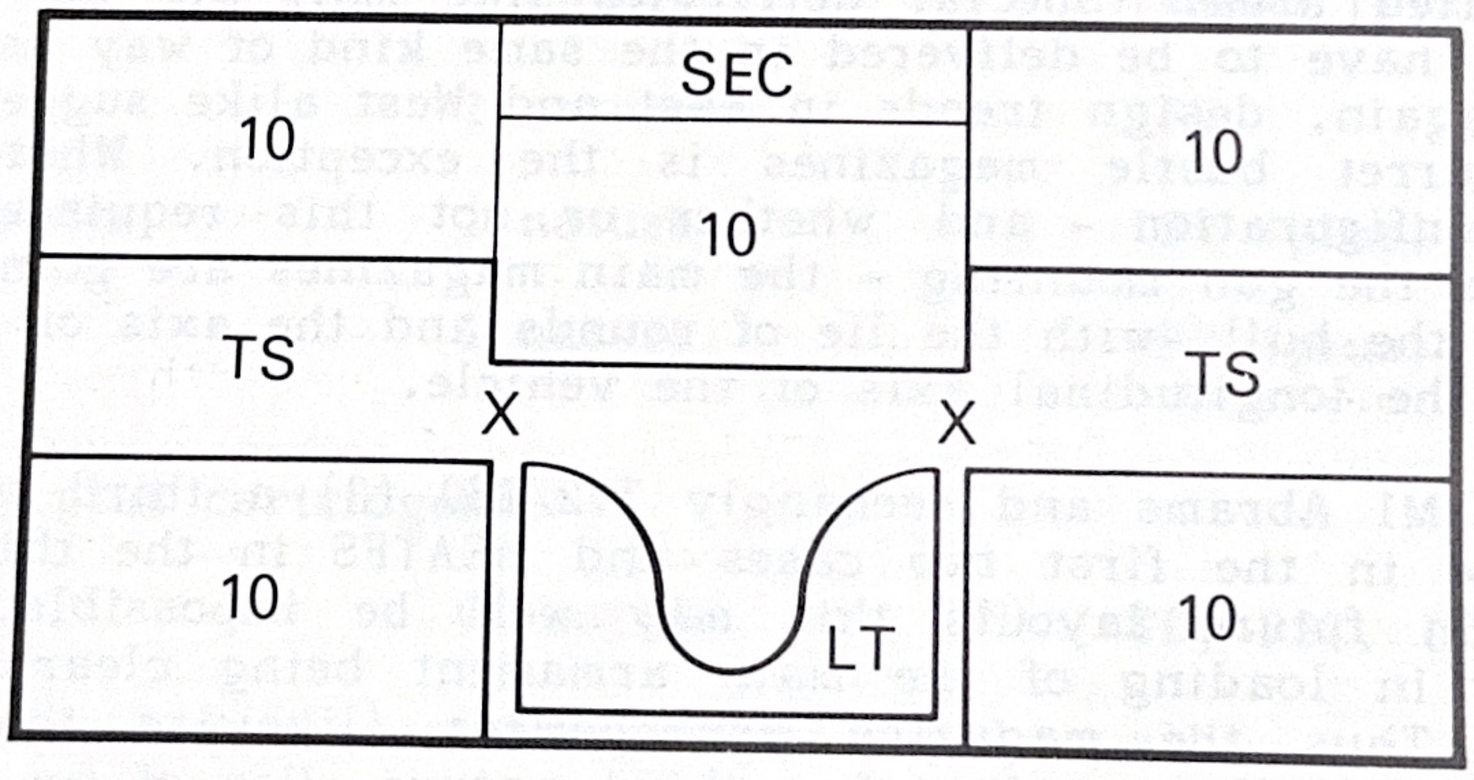

Figure 7. Magazine configurations.

LT = loading tray, SEC = secondary ammunition etc (see text), TS = transfer space. This schematic is envisioned for a fixed-gun tank and dimensioned on 120 mm munitions (+ 20 %). For an external gun either this layout could be retained and the loading tray brought forwards and upwards, or the arrangement could be inverted. This layout allows either an integrated design, or a 3 or 6 module arrangement. It would be possible to save height while retaining the essential feed gaps X, X by putting a compartment for secondary ammunition etc at the outer end of the transfer space on either side.

We can now turn to the delivery aspect with a clear understanding of the problem if, as yet, little idea of how to solve it. Evidently it is a two-ended problem in which the supply truck and the delivery technique are at a crunchpoint between the functional requirements of the magazine on the one

hand and organizational and logistic constraints on the other. So I must ask the reader to accept, until I get around to justifying it, that one would like this dedicated ammunition supply vehicle to carry 4 magazines and to be based on a "dead" body. This said, let us proceed in discrete, if not exactly easy stages, starting with the **supply vehicle.**

The need for off-road mobility rules out drawbar trailers and conventional semitrailers. I must admit to prejudice against the "goer" configuration; but I guess I can justifiably rule it out here as not cost-effective for a dense payload of only 9 t. Mideast and other extreme conditions may well call for a tracked chassis at least forward of division, but for developed theaters a rigid truck with all wheels driven and slipping differential locks (laterally and fore-and-aft) would surely be adequate. Whether the prime mover is tracked or wheeled, it will have to carry a horizontally (longitudinally) loaded swop body; this will add around 5 % to the effective payload weight (8). Whatever form of handling system is used, it may need to be operated independently of the prime mover; and in any event a dedicated chassis can with luck be avoided. So the weight and space requirement for the handling equipment must allow for a motor-generator/compressor/pump group. Diesel-hydraulic has the edge, maybe, because it can safely be operated in the vicinity of a refueler; additionally it is suitable for differential jacking to level the platform.

We can now think in terms of a platform with 6 magazine-sized spaces - 4 to hold magazines, 1 to play solitaire with and 1 for the handling equipment and its control station. This means a platform roughly 6 m x 2 m. A probable magazine width of rather under 2 m plus 10 % tolerance on the supply vehicle (9) is the first of the arguments leading to sideways positioning (4 x 1, fig 8a) of the magazines, with tail delivery. The second argument is that 2 x 2 loading may call for the magazines to be leapfrogged on either of two axes (longways and crossways) and puts the empty space alongside the handling equipment. With the 4 x 1 layout the operator can put the empty space wherever he wants.

This layout also offers a remarkably simple handling arrangement, well suited to hydraulic operation, in the shape of an overhead crane on a central beam running the length of the platform with a rear overhang (fig 8b). Without doing the sums, I would guestimate that 3 arches would suffice for a 2.25 t payload, giving a 3 m run of beam between them with 1.5 m in cantilever at the rear. Twistlocks (body to chassis) could be incorporated in the bases of these arches. If the magazines are moved by lifting, it is very simple to locate them positively on the platform, using shaped wedges and recesses to guide them into position (fig 8c). Additionally, a suspended load of this size and weight can easily be steadied or turned through a few degrees by one man.

Thus the driver and codriver of the truck, one at the handling controls and one at the load, can exchange the magazines without help from the crew. A final advantage of this layout is that the payload can be jprotected by a conventional tilt with a superstructure based on the arches supporting the crane. Taking account of all this, we might ballpark the laden body weight at 12 t (133 % of basic payload), an easy figure to accommodate.

We can now turn to the problem of **magazine exchange**, starting with the armored vehicle backed up to the rear of the truck with the aid of the reverse driving video system, guide markings on the truck and the truck codriver's hand signals. At this point we need to look at the design of the **magazine hatch** (fig 9). Since the magazine has to be jettisonable by explosive charge in emergency, it must be inserted and withdrawn horizontally from the rear. For the same reason the "hatch" - in fact the whole upper part of the hull rear

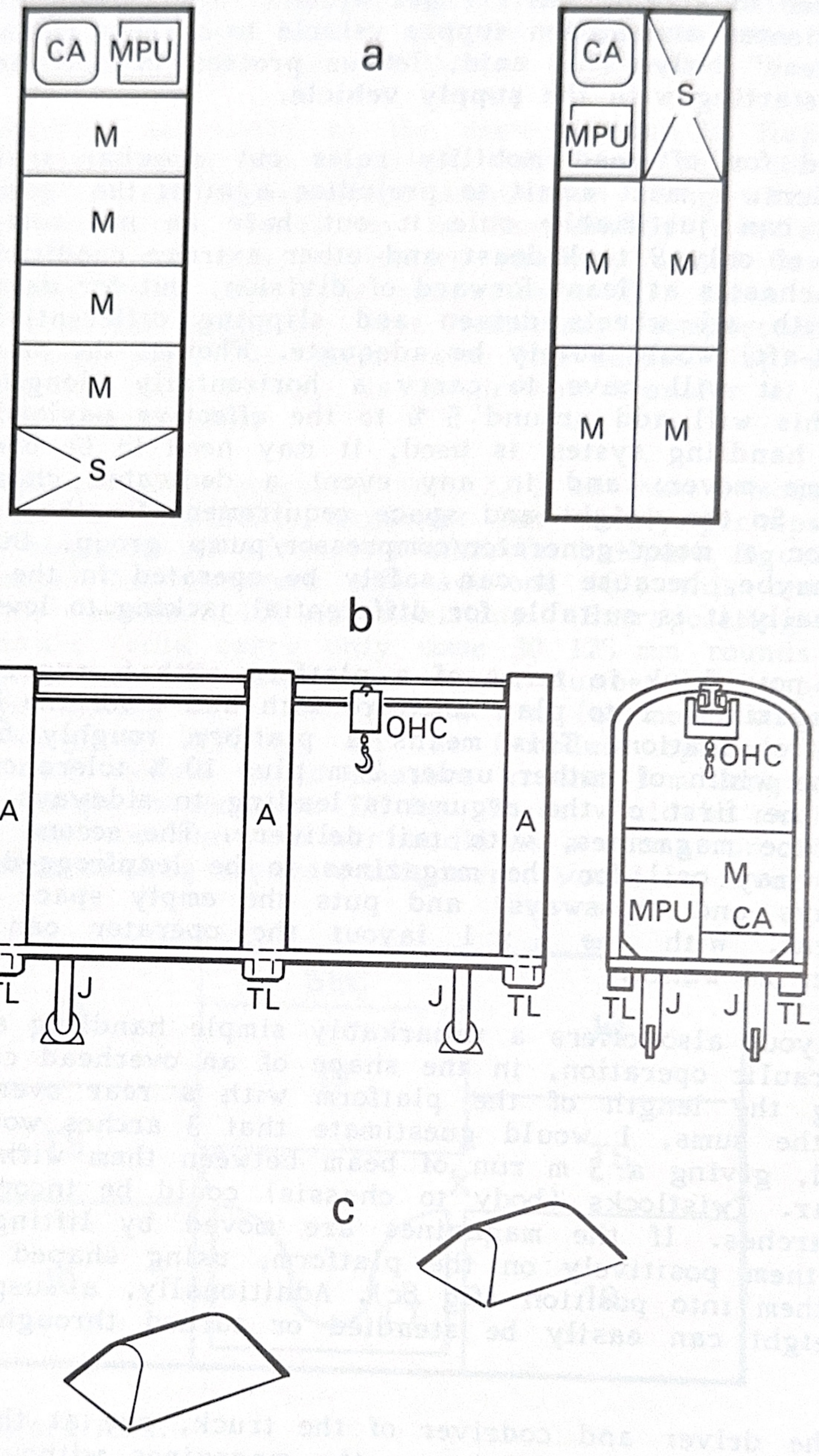

Figure 8. Ammunition supply body

a. 1 x 4 and 2 x 2 layouts. CA = control area, M = magazine (complete), MPU = motor-hydraulic pump unit (also supplies control electrics 24 v DC stabilized), S = space

b. Magazine carrier body (see text). A = arch, CA = control area, J = hydraulic jacks (wheeled leg), MPU = motor-pump unit, OHC = overhead crane (hydraulic), TL = twistlock

c. Multiface wedges on platforms (2 per magazine space) matched by recesses in underside of magazine.

between the tracks - should be bottom-hinged. The hatch needs to extend forward at roof level by rather over 0.5 mm, possibly with a central tongue extending the same distance again. Reduced thickness of the horizontal part compared with the roof plate proper would entail a slight tradeoff in direct protection. But the benefits are a minimal risk of jamming when jettisoned, optimum ease of exchange and easy external access to the autoloader. Normally the hatch would be operated by the crew via a power supply shared with the autoloader; however with a weight of 200-300 kg it could be opened and closed by four or five men in emergency (or by the supply vehicle's hoist, or a repair/recovery vehicle's jib).

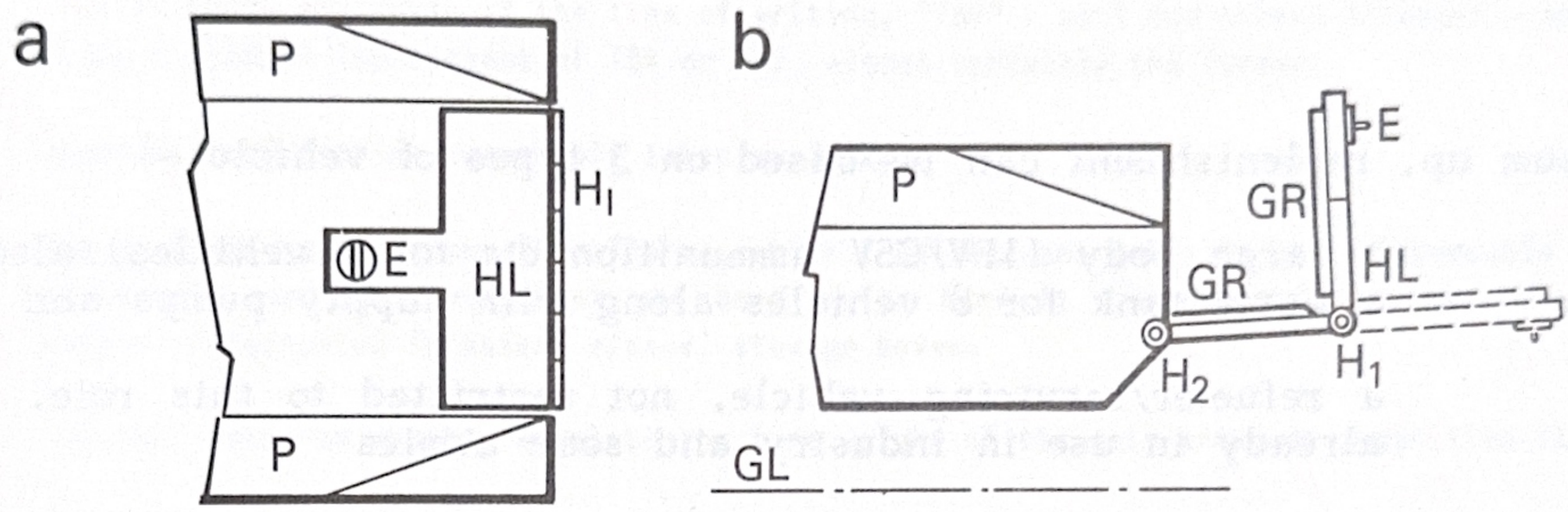

Figure 9. Magazine hatch

a. Plan view, hatch closed

b. Side view, hatch half open (fully open position shown dotted). E = emergency lifting eye (if power actuation fails), GL = ground level, GR = guide rail, H_1, H_2 = hinges, P = pod (sponson) over running gear, HL = hatch lid.

Presumably the magazine would have a recessed lifting eye (or the equivalent) top center. With the shape of hatch suggested, the hoist on the supply vehicle could place the magazine on rails past its point of balance and possibly guide it home. The action of closing the hatch would then lock the magazine into position. Similarly the magazine would be unlocked by the action of opening the hatch and then taken over by the hoist or, for work on the autoloader, the jib of a repair squad vehicle. With these arrangements on supply vehicle and armored vehicle, there is no need to level the supply vehicle body. The only restriction on the armored vehicle's attitude is that it must not be nose down; and the two vehicles need not be precisely aligned.

I have digressed at considerable length to demonstrate the feasibility of the single magazine concept because I believe it to be of key importance both for speed of replenishment and for replenishment and autoloader repair under NBC threat or contamination. *Mutatis mutandis* the approach may also be of interest in the context of the very serious problems of turning around fixed and rotary wing aircraft under NBC contamination. Likewise it is a first step towards even more interesting possibilities in armored vehicle design (Chapter 15).

We might finally look at what happens to the empty or part-empty magazine at the bulk-breaking and crossloading point. Magazines may be superficially contaminated. They would be offloaded from the supply vehicle onto a gravity conveyor which would pass them through a decontamination unit (10), and thence into a protected working area. Here the rear panel would be removed,

the interior inspected and if needs be cleaned or repaired, and the magazine recharged as specified by the tactical commander. Differing loadings for TD and FST would be identified by a panel of distinctive shape, color and surface texture attached to the top of the magazine (11). Recharged magazines would leave the protected area by conveyor and be lifted by the supply platform hoist or any convenient means onto a row of "dead" platforms (on jacks) which the prime movers had exchanged for full ones. Thus prime mover turnaround would be a matter of minutes. With 3 x 2 loading of platforms, magazines could be serviced on the platform; but there is no very evident advantage in this, and the 3 x 2 pattern greatly complicates the supply platform. The process I have described could be carried out on a series of trailers or swop bodies, in workshop-type tents or in factory or farm buildings.

To sum up, replenishment can be based on 3 types of vehicle -

a cargo body (IFV/CSV ammunition etc for 4 vehicles) also carrying a water tank for 8 vehicles along with supply pumps and hoses

a refueler/servicing vehicle, not restricted to this role, of a kind already in use in industry and some armies

a dedicated swop body for TD and FST magazines

Since the magazine carrier has to be a swop body and, at the ballpark level, the weight or bulk of each type of load looks to require a vehicle of around the same size, the arguments for incorporating all these types into a body swopping system with common prime movers start to become irresistible. Fact is it restores the flexibility of the good old days of drums or jerricans and boxed ammunition; we shall see further arguments for this approach in Chapter 15. So let us assume it. Extreme terrain may call for tracked chassis. But because the speed of replenishment attainable with these vehicles allows running replenishment to be used with minimum tactical risk, standard all-wheel-drive 10-15 t rigid chassis would have adequate off-road performance in the combat zones of most theaters.

Commercial grade chassis towing similar skeleton drawbar trailers could be used further back, as could double-length skeleton semitrailers. In fact the platforms could conform to the plan dimensions of ISO-containers. Before looking at running replenishment procedures in more detail though, we should note that undeveloped theaters might call for a basic tracked chassis/cab for use forward, backed by high mobility as opposed to commercial wheeled vehicles.

Notes

1 Normally that, at the warned and protected risk level, one 5 kt weapon will not knock out more than a tank platoon.

2 Chapters 16 and 24.

3 From evidence available at the time of writing, "T80" - as I and others forecast - appears to be a product improvement of T64 or T72, almost certainly the former.

4 Generally and I think reasonably taken as 30 kg.

5 The greatest hazard comes from flares, which I believe are going to be indispensable in an electronic warfare environment and must be to hand at the command stations. They may require fireproofed (pressure sleeve) stowage boxes.

6 Together taken as roughly equal to the bare weight of the main armament ammunition itself.

7 For instance the 41-42 t Soviet T72 carries 40 rounds of 125 mm separate ammunition in the autoloader system, apparently with a fixed breakdown of types (18 APDSFS, 22 HEFS). Although the 125 mm stowage of this tank is generally quoted at 40, the 6 manually loaded HEATFS rounds may be additional to this; or they may replace HEFS rounds.

8 This 5 % will in fact be split between body and chassis/cab, but no matter.

9 This is the "normal load" maximum towards which most countries seem to be (steadily) gravitating.

10 Suitable equipment is in service within the Soviet division.

11 Other aspects of task-orientated loading are discussed in the next chapter.

CHAPTER 13

Replenishment Organization and Procedures

Traditional in-lager replenishment tied a tank company to its supply packet (which might be organic or come from battalion or the divisional train) for a matter of hours. Nuclear dispersion apart, it is seldom feasible or tactically safe in European terrain to form the kind of tight "hedgehog" familiar in desert, steppe and open plain. So we arrived at the "muddy forest ride on a dark wet night" scenario to which I and some of my reviewers are so fond of referring. As tanks grew thirstier and their guns larger, this process was seldom completed in less than 2 hours. Then came nuclear dispersion. This added something to the duration just from the time trucks take to cross bad going in the dark. But it added a great deal more from snafus like drivers getting lost, trucks getting bogged and platoons having to be revisited because the first vehicles to go to them had run out of a particular type of lubricant or ammunition. The whole business became less and less acceptable just in terms of tactical risk and fatigue. Once tanks gained genuine night-fighting capability, it became unacceptable period.

With its fuel in expendable 40 gallon drums and its ammunition in expendable packaging, US Armor was already using *ad hoc* forms of running replenishment back in World War II. For a long time the British were tied to the jerrican, non-expendable even in war; but as soon as bulk refueling came in, British Army of the Rhine started experimenting - mainly through initiatives at combat team level - with running replenishment. This changeover brought many real advantages but a number of illusory ones too. With their ammunition, sometimes bare, and/or their fuel dumped onto their engine decks, tanks could pass through these early running replenishment points very rapidly. But they then staggered off in a highly dangerous state and had to spend the next hour or two sorting themselves out.

So one half of the problem was solved; the supply trucks were tied down in the combat zone for minutes instead of hours. But the tanker's difficulties were changed in nature rather than eased; companies were still "down" and vulnerable for a matter of hours.

For any number of self-evident reasons, the goal for the nineties has to be **a type of running replenishment which ties down both combat and supply vehicles for minutes only and can be carried out with contaminated vehicles or even in a contaminated area.** I reckon I proved the technical feasibility of this in the previous chapter. I now want to do the same for the organizational and procedural aspects, fully admitting that broader-based wisdom, in-depth studies

and trials might well prove my suggestions impracticable as they stand and would undoubtedly produce far sounder solutions.

I said earlier that the capacities of ammunition trucks should be geared to the complete replenishment of 4 vehicles, and that of refuelers to 8. This was based on the composite company within a composite battalion that I finally took as a model in *Antitank* (1), reproduced at figure 10. A composite platoon - a handy and safe size of subunit to plan replenishment on - consists of 4 FSTs (magazines) and 4 IFVs/CSVs (manual bombing up). If it has a TD section with it, the platoon will need one additional magazine truck. With 9 "magazine" vehicles, the antitank platoon as a whole is a misfit. But if the tactical commander orders a different loading for TD and FST magazines, a packet of 6 trucks with 3 carrying two TD plus two FST magazines and 3 one TD plus three FST magazines gives high flexibility. Likewise 5 refuelers can completely replenish the company. Five cargo/water trucks would be needed, basically 1 per composite platoon and 2 to cover the headquarters plus the antitank platoon.

Although this company contains 38 major armored vehicles, something not too far short of a conventional tank battalion, the use of 16 supply vehicles and 42 men to replenish it looks extravagant - although the percentage of administrative personnel does not compare unfavorably with any existing Western organization. In my approach I have made a conscious decision to take two large steps forward - instant bombing-up and safe replenishment under NBC conditions - and to pay the price of these.

In any event the logistic compensations are substantial too, though less self-evident. The incorporation of all these primary supply vehicles in a body-swopping system on a choice of common chassis adds up to a major economy. For handling and movement outside the combat zone these bodies could be carried, maybe stacked two deep even, on commercial grade chassis towing a basic skeleton drawbar trailer, or on a double-length semitrailer. Thus the number of expensive prime movers can be restricted to the lift forward of the divisional train. Additionally the turnaround time of these off-road prime movers is reduced from hours to minutes **at both ends** (running replenishment point and commodity/delivery point). They are tied down only when held forward loaded. The same applies to the 42 men required; they will be far more highly utilized than is usual with logistic personnel, at least in Western armies.

I guess, though, it is worth probing the logistic implications a shade more deeply. Evidently the company's small **services platoon** of 21 all ranks (Table 3) cannot provide this lift. As I argued in *Antitank* (2), I do not see this as its role. The **control and administrative section** finds 2 teams, each mounted in an AVR(W) and a jeep equivalent, to guide replenishment packets and to reconnoiter, plan and supervise running replenishment points. This section also holds the company's general stores. The **emergency resupply section** is just what its name indicates; organic personnel and vehicles are needed to get a magazine to a vehicle which has jettisoned one or to refuel a vehicle which has run out near the forward edge of the battlefield.

The **technical section** controls all the company's technical resources, minimal spares being held in the "survival packs" on platoon CSVs and on the electronic repair vehicle. Technical personnel in fact total 12, split evenly by trades (see also note to Table 3). Because they need special test equipment and maybe a controlled working environment, the electronics specialists remain as a team in a dedicated vehicle. The technicians carried in platoons (page

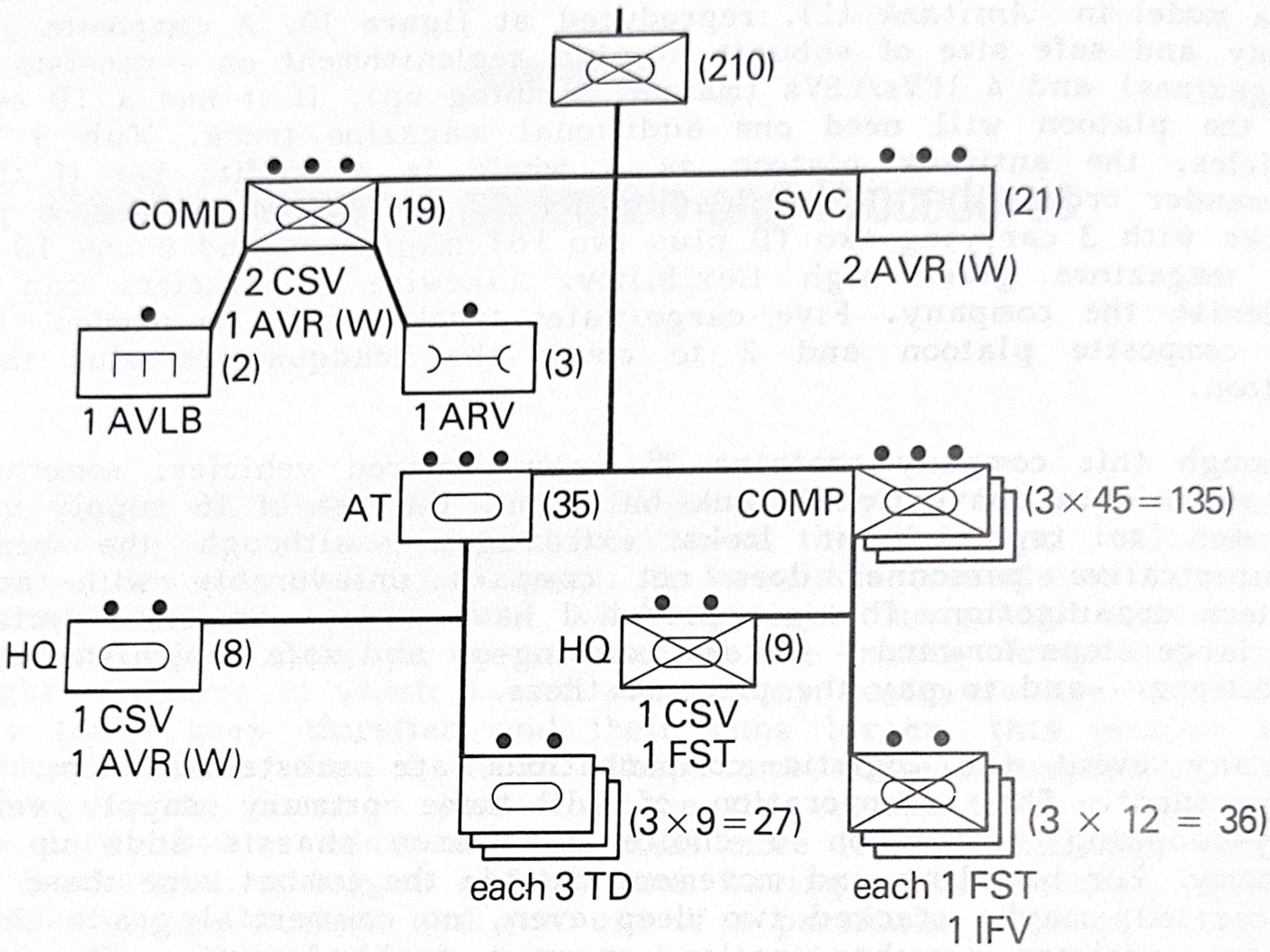

Figure 10. Composite company

Strength - 210 in all ranks
9 tank destroyers (TD)
12 fire support tanks (FST)
9 infantry fighting vehicles (IFV)
6 command and support vehicles (CSV)
1 armored vehicle launched bridge (AVLB)
1 armored recovery vehicle (ARV)
1 APC, light, repair
4 armored vehicles reconnaissance, wheeled (AVR(W))

Logistic vehicles in services platoon -

2 truck 1/4 t
1 truck 12.5 t (cargo)
3 prime movers 12.5 t

plus

3 swop bodies 12.5 t (normally 1 magazine carrier, 1 POL, 1 cargo/water)

Table 3. **Services platoon of a composite company**

Control and administrative section

Officer (or warrant officer) commanding, platoon sergeant*, 1 staff sergeant, 1 sergeant, 1 corporal plus four (9)

2 armored vehicles reconnaissance (wheeled), 2 trucks 1/4 t (or equivalent) with radio, 1 cargo truck (corporal driver-storeman).

Emergency resupply section

1 corporal plus five (6)

3 prime movers, normally loaded - 1 magazine carrier, 1 refueler, 1 cargo/water body.

Technical section

1 master sergeant (also responsible for ARV crew (3 automotive/recovery technicians) and armament/recovery technicians in antitank and composite platoon CSVs (4), (see page 71), 4 electronics technicians, 1 automotive/recovery technician**

1 armored vehicle reconnaissance (wheeled), 1 electronic repair vehicle (light APC variant, fitted with jib)

* Separate rank in US Army

** Providing 4 specialist tradesmen in each field, 12 in all. Armament technicians are also trained in power electrics and have **basic** knowledge of battle recovery. Automotive technicians are recovery-trained. Electronics technicians also cover telecommunications and include one staff-sergeant equivalent.

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71) should be armament-oriented (with basic knowledge of battle recovery), while the ARV crew and the section's AVR(W) driver would be automotive/recovery specialists.

Once all main replenishment commodities are incorporated in a body-swopping system, the off-road prime movers should be organic to battalions and handled at battalion level until packeted and allocated to companies, when a company control element would take them over. Since in fact these company packets will return with part loads, economies would be achieved by limited crossloading, even between magazines, at battalion level. When empty or nearly so, the vehicles go back to the divisional commodity/delivery point to swop bodies. With the exception that the key logistic levels differ from those now used in the US Army, this is all very conventional.

In my experience the practice of through-running logistic unit vehicles known as **forward supply** never worked particularly well with armored units. Its main purpose was to avoid crossloading ammunition, a secondary one being to keep bulk refuelers under specialist control. With the magazine and swop body system I suggest here, these advantages are nullified. Let me stress, though, that forward supply remains by far the best principle for artillery ammunition and resupply into division.

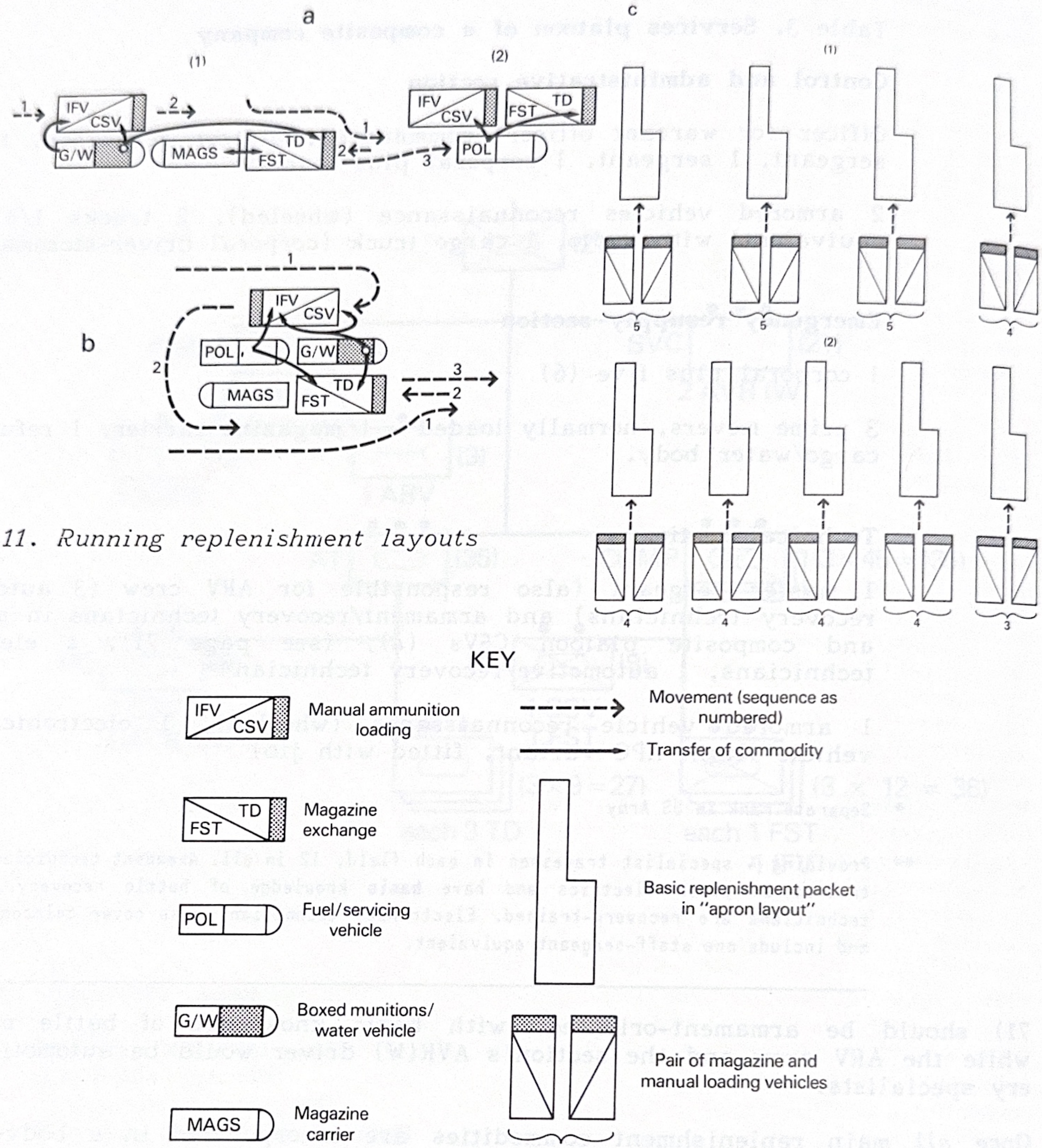


Figure 11. Running replenishment layouts

Roadside layout. Basic 3-vehicle element in two groups (1) ammunition/water (2) POL. Maximum width 1 armored vehicle plus 1 supply vehicle. This layout can be repeated along the road, but not laterally.

b. **Pull-in/apron layout.** Basic 3-vehicle element in one group with space for armored vehicles to maneuver round it. The apron layout consists simply of lateral multiples of this arrangement.

c. **Company replenishment in apron layout**

(1) 4 x 3-vehicle elements deployed, 1 in reserve. This clears a platoon in 15 minutes, and the company of 38 major armored vehicles in 75 minutes.

(2) 5 x 3-vehicle elements deployed, leaving only companies' organic emergency resupply sections in reserve. This clears the company of 38 major armored vehicles in 1 hour, with a small reserve capacity for attached and/or light armored vehicles.

Having spoken of completing replenishment in minutes rather than hours, I now need to prove this point. A key parameter in running replenishment is the width of carriageway, hardstand or open level ground available. There are probably three critical widths (fig 11) -

"roadside"	packet and armored vehicles each occupying a single vehicle width, "longitudinal multiples possible.
"pull-in"	packet occupying two vehicle widths, with room for armored vehicles to turn at either side, longitudinal multiples normally impossible
"apron"	lateral multiples of the "pull-in" situation

Recapitulating, replenishment should be physically based on a large platoon or equivalent group of 4 pairs of vehicles - that is 4 TDs/FSTs and 4 IFVs/CSVs. The replenishment packet for this group contains 3 vehicles -

1 refueler (8 armored vehicles)

1 magazine carrier (4)

1 cargo/water truck (ammunition etc 4, water 8)

The company packet consists of 16 load carriers (the prime movers being organic to battalion) and up to 4 control vehicles (organic to company).

We next need to look at times for individual operations. Taking fuel first, and extrapolating from Leopard 1 to a high mobility MLC40 vehicle (3), we could expect a nominal consumption of 1.42 l/km (0.60 US gals/mile), so that a range of 600 km requires 850 l (225 US gals). (This incidentally puts the capacity of the 8-vehicle refueler at 7000 l or 1800 US gals, which looks about right for a swop-body of the size and design envisioned.) If, as is predictable, the armored vehicle's fuel tanks are shaped to form part of the armor system, there is little hope of achieving aircraftlike filling rates; but a maximum flow rate of 150 l/min (c. 40 US gals/min) should be attainable. This gives 6 minutes for a complete refuel; allowances for moving up and away and for opening/closing fillers extend this to **a practical target time of 10 minutes for refueling** (and topping up with "technical fluids").

With **magazine changing** we are on shakier ground. Provided that the crew of the magazine carrier know whether the next vehicle up is a TD or a FST (if magazines for the two are differently loaded), and that the armored vehicle opens its magazine hatch while backing into position, it should be possible to exchange magazines in 5-6 minutes. So we can postulate a matching **practical target time of 10 minutes for a magazine change.**

As long as the **water** supply unit has a reasonable delivery rate, time is not likely to be critical. Likewise it should be feasible to transfer ammunition and rations manually from truck to IFV/CSV rear compartment in around 5 minutes with a dropside truck body and one rear door of the IFV/CSV open. But unlike the weapon platforms, the vehicle is not then ready to move off and fight; the ammunition has to be stowed and belts for automatic weapons may have to be linked to the tails of existing belts - not the simplest of operations on the move. So if bombing up and refueling are done consecutively, bombing up should take place first. If the two operations are simultaneous, the IFVs,

which may need substantial quantities of ammunition, will require a pause to sort themselves out.

It looks as if the best reasonable target times for a pair of armored vehicles are **20 minutes for the "roadside" situation**, where the two main operations are consecutive, and **15 minutes for the "pull-in" situation.** Extending this to the platoon in terms of a basic supply element, the "roadside" situation allows pairs of vehicles to overlap at the two points, giving a total of 50 minutes. With the "pull-in" layout, 5 of the 15 minutes are required for the IFVs to stow their ammunition. This can be done away from the supply vehicle, so the total time becomes 45 minutes. Either way, with a sensible snafu factor, it takes **1 hours to replenish a platoon from a single basic supply packet.**

This is a tough figure to stomach in face of a massive investment in dedicated swop bodies for replenishment. Quite simply 1 hour is not a tactically acceptable down time for a mechanized platoon, though I believe 1-1½ hours **is** an acceptable time for supply trucks to be tied down. (Evidently these must arrive first and depart last.) But there are several letouts.

I tied the basic supply packet to a platoon or similar grouping because this is the smallest subunit likely to be detached over a time and/or distance long enough to need separate replenishment. If, as it normally will, the total situation allows a company running replenishment point to be set up, the procedure becomes completely flexible. The company packet is made up of 5 basic elements, of which 1 effectively represents a reserve. So 4 packets can be set up together, either longitudinally in the multiple "roadside" layout, or laterally in the "apron" pattern. With good control this should clear a platoon in the basic target times of 20 and 15 minutes respectively.

Since the company in fact holds an organic basic supply packet as an emergency reserve, the fifth basic element could safely be deployed to handle the 4 major armored vehicles of the headquarters platoon, the antitank platoon CSV and at least one TD (plus any attached CSV variants, such as a forward observer's vehicle). This allows the whole company to be cleared within 1 hour on either layout. These timings are much more acceptable.

A hidden plus in all this is that, because of the NBC threat (or actuality) the replenishment procedure has to be planned and manned with participation from armored vehicle crews limited to moving the vehicle as required and carrying out certain specific operations. Thus, specially in the cases where a particular armored vehicle is tied down for an hour or so, the crew can use this period to feed, wash, carry out checks and adjustments and generally sort themselves out. Twenty-three hours out of 24 are available for fighting or moving, and for rest.

It is in fact refueling during and/or immediately after operational or long tactical moves which is the replenishment situation when minutes really matter. With 4 refuelers spread along the roadside, groups of 8 vehicles can be cleared in 10 minutes - probably less because of the simplicity of the operation. The fifth refueler can be held in reserve unless the refill is over 80 % of capacity, when the grouping for movement must be varied to make use of it.

During a move, though, it is the time for which each vehicle is halted that counts, not the total replenishment time. To minimize delay, a group must clear the replenishment point as the next one arrives. At a speed of 90 kph and an average traffic density of 2 vehicles/km - probably the minimum figure acceptable in terms of control, security and route space - the time interval

between groups would be less than three minutes. So to minimize delay 4 packets of 5 refuelers each are required.

This can be achieved at battalion level, still leaving the company's emergency reserve intact and a full battalion slice of ammunition on organic wheels. With 155 major armored vehicles and 10 light tracks, there is just sufficient capacity for this. Alternatively and preferably, since a move of this kind would be mostly on main roads, a battalion could be refueled by 10 truck-trailer trains, leaving unit holdings intact. Since the number of refueler bodies on wheels (or capable of being put on wheels) within a divisional train has to equal the number of bodies on battalion prime movers, this principle can be applied for larger-scale moves.

Before leaving this aspect, we should maybe attempt to relate the on-vehicle capacities and holdings in units and divisional trains to consumption expressed in **days at medium intensity** (4). Leaving aside the company emergency reserve, battalion and divisional train holdings each match the on-vehicle capacities. In *Antitank* (5), admitting to more of a guess than a guestimate, I put the logistic requirements for a high-tempo battle as 6 hours (i.e. a quarter day) at 30 minutes notice, 24 hours at 2 hours notice and a further 24 hours at 6 hours notice. It is just as hard to ballpark the number of days of high tempo operations represented by the on-vehicle capacities, but for medium intensity one might pitch in 2 days (though my "feel" is for 3, so this is on the safe side). Then the "6 hours at 30 minutes" requirement is more than met by the basic 3-4 vehicle element (nominally 1 refueler, 1 magazine carrier and 1 cargo/water truck plus an additional refueler or magazine carrier as reserve) - in other words 25 % of the company packet. "Twenty-four hours" at medium intensity is 50 % of the company packet.

The normal principle of topping up forward load by load would apply; unless contamination or weather conditions prevented it, crossloading of commodities between part-empty vehicles could take place within the company packet and/or when vehicles are marshaled at battalion. Frequently TDs and FSTs will have used some secondary ammunition, flares for instance, without firing their main armament. They can be topped up from a cargo/water truck through the commander's hatch, using the anticontamination drill proposed for spares (page 71). The magazine exchange principle is a great step forward as long as it is applied with common sense and not allowed to become a sacred cow.

In sum, then, 2 days are held on combat vehicles, 2 days on wheels forward and 4 days in the divisional train. Thus 8 days at medium intensity are held within the division. Since there is no reason to suppose any change in the old yardstick of fuel plus ammunition lift being constant for mechanized forces, bulk lift into division - presumably on the forward supply principle - presents no new problems.

Fact is, the control and disposition of replenishment vehicles will change little from the system practiced by most armies for decades. Nonetheless the tempo of operations as a whole and of replenishment in particualar, along with the effective shift of the bombing up problem from tank crew to logistic element, calls for excellent command and control. This is why I provided for 4 control teams in the services platoon.

The company's organic emergency resupply section, mostly used to resuscitate a vehicle casualty, would be controlled operationally by the noncom in charge of the technical section. When none of them was deployed, I would see these load carriers forming a movement packet with the technical section vehicles, the ARV and the AVLB. When used, these vehicles would be topped up by crossloading, magazine exchange or in the extreme swopping bodies from the company packet.

This technical/emergency packet would move as close behind company headquarters as safely permitted.

As I see it the officer (or warrant officer) commanding the services platoon, normally mounted in an AVR(W), would pair with the staff sergeant in a jeep, likewise the platoon sergeant with the sergeant. At any one time one pair would be split, the senior member reconnoitering replenishment sites, the junior one guiding a replenishment packet of full vehicles forward from battalion. Unless the company is split, requiring two packets, one member of this pair will mostly be available to help in the control of replenishment.

The other pair is with and in control of the company packet, its senior member having already reconnoitered and planned the next replenishment. If a small element is required to go forward and provide a quick top-up, he takes it. Hopefully any resulting individual empties can free-run back to battalion. After major replenishment, the junior member of the pair leads the empties back to battalion and waits to bring their replacements forward. By this time the first pair will have taken over control of the replenished company packet, leaving the senior member of the second pair free to rove. Thus one pair can in fact always be made available to battalion for a centralized replenishment operation like the en-route refueling discussed above.

Equally important is control of the replenishment procedure itself. The junior partner acts as traffic controller, checking armored vehicles in and directing them by hand or light signal (or radio) to a particular group of supply vehicles. The senior partner moves around, probably in his vehicle, whipping in any armored vehicles that are dithering or straying, sorting out snafus and, for instance, ensuring that TDs and FSTs get the appropriately loaded magazine.

The feasibility of the kind of approach to human factors, specially to the problems of NBC threat and contamination, that I have developed and will develop in the other Parts of this book stands or falls on logistics. I believe I have shown that the provision of dedicated supply vehicles, a considerable rethink of procedures and, above all, a radical change of attitudes can offer an effective and cost-effective logistic backup capable of bringing crews and their vehicles to battle truly fit to fight, of sustaining them in combat and of responding to the predictable tempo of the maneuver battle of the nineties.

Notes

1 Figure 26.

2 Chapters 23 and 24.

3 Available figures suggest this is reasonable enough if one assumes a high-performance compact diesel rather than the thirsty gas turbine of M1 Abrams.

4 The normal ratio of low/medium/high intensity is 1/2/3.

5 Chapter 24.

Part 3 Fighting

CHAPTER 14

Background Factors in Crew Morale

Many readers will feel that this book puts two carts before the horse. Certainly when I was involved at national and international levels alike in the infighting of armor policy, striving to claw back an apparent Soviet lead and maybe gain an edge on the Pact, I would not have seen things this way round. With hindsight and standoff, though, I reckon that, however liberal their superiors, the makers of American, British and maybe West German policies on future equipment live in a mental straitjacket of which neither they themselves nor others in the game are aware. The justification for serving officers - "users" - working in this field is their experience preferably of war, certainly with troops. Yet even experience takes a back seat when its lessons are unpalatable.

Napoleon's dicta may have become cliches, but this confirms rather than impairs their validity. Men have to be brought to battle mentally and physically fit. Once battle is joined or rapid movement is the order of the day, they have still - as Xenophon reminds us - to be fed and rested. Unless something very deliberate and rather expensive is done about it, a defending mechanized force will finally go into action mentally depressed and physically run down and flabby, and will quickly fight itself to a standstill. The combination of little tin boxes and the NBC threat puts a premium on conserving personal pride, maintaining health and relieving fatigue. Armored vehicles must be truly habitable and have excellent logistic support if their fighting power is to be realized.

In subsequent chapters we will examine major facets of the interface between morale and design. First I want to address some broader questions which impinge on what one might call design style and on the conflict between performance and reliability. While there will always be hawks and doves amongst the political leadership, the climate of Western popular opinion looks to be marked by two trends which at once merge and conflict. On the one hand there is mounting rejection of war between organized forces as an instrument of policy; on the other there is increasing tolerance of terrorism and guerrilla warfare, even tacit acceptance of these as an inevitable and justifiable response to deprivation or oppression - or even a proper expression of political disagreement. Mechanized forces are definitely about operations of at least medium scale and intensity; so their soliders and the men who command them are more and more faced with a problem of conscience.

This problem is lucidly if unconvincingly expressed in Strategic Air Command's

motto "Peace is our profession." But at grassroots level it is not easy to explain to men in one breath that they are there to prevent war and in the next that they must undergo the rigors of training, let alone plunge into extreme danger. When the outbreak of hostilities amounts to failure, they may see little to be gained by fighting.

This is a contradiction which the sophisticated intellect of the officer seems able to resolve but the simpler mind of the enlisted man finds hard to live with. It stems from political hypocrisy and to this extent lies outside the scope of this book. But it is a fact of military existence in peacetime which commanders at every level have to take account of. The conventional response is to play down warlike training and to focus attention on sport, social life, social work in the shape of relations with the local population, travel and prowess in traditional military activities which patently have no bearing on modern war.

This is the conventional response but not necessarily the right one. In my view, if one volunteers to join the armed forces, he enters into a contract which calls on him to fight - and thus to kill and maim other people and expose himself to fire - if called on to do so. Equally he has the moral right to opt out if required to participate in activities which offend his conscience, for instance arms sales or the massacre of civilians. At root the draftee is faced with the same problem; but few have the moral courage to become conscientious objectors. At any rate every army I know of - except the Swedish, Swiss and Israeli forces - conspires to make its conscripts' life so wretched that they are fully occupied in coming to terms with it or in using drink or drugs to distance themselves from it. Theirs **is** to reason why, but they are given no chance to get around to doing that thing.

I share the view of most British and many United States officers - many German ones too when they venture to express it - that to be effective armored vehicle crews have to be made up of relatively long-service volunteers, even if most or all of this service is spent in reserve units which undergo regular training. Conscript armies with large and effective armored forces, notably the Soviet Army, seem apt to seek a compromise in a combination of elitism and slightly less intolerable conditions, thus in effect creating surrogate volunteers. So let us suppose that armored vehicle crews are there because they want to be, even if only as a lesser evil.

Commanders need to build these men's morale on a firm basis of moral and physical preparedness for war rather than a hypocritical tightrope. Likewise they must seek to develop the accepted discipline called for by "mission-type control" rather than the imposed discipline associated with the "detailed-order tactics" of the Soviets and others (1). One aspect of this approach, in which the unionization of armed forces looks to play an important part, is not directly relevant but too important to pass unmentioned. Authoritarian determination to impose a stamp has to be replaced by the more liberal path of creating an environment in which men can develop their characters in the direction needed, and in which the small number of goats quickly sort themselves out from the sheep.

The other facet is to make training and living in the field not just interesting but actively enjoyable. I am not suggesting that armored vehicles should be designed as fun buggies, but I am saying that they should as far as possible be styled inside and out to make them exciting and attractive to the type of young man who makes a good tank crewman. This is exactly the kind of appeal that going to sea and flying, and the ships and aircraft - notably fast patrol boats and fighters - which make these possible, have for officers and enlisted men alike. I can confirm from my own feelings that armored vehicles once had

the same appeal. Now, as I remarked in *Antitank* (2), they no longer have this appeal for potential young officers who have grown up with around the same level of gadgetry. But they can have for suitable enlisted men brought up at a lower standard of living.

I cannot completely verbalize the style required. To see one side of it, you only need to look at a traditional sports car or a WWII fighter like the Spitfire. The controls of a modern armored vehicle do in fact allow a man to bring great power to bear with little effort; their styling and responses should reflect this. At the purely physical level a long life without loss of reliability, allowing the vehicle to be used freely, is a key factor. Avoidance of automotive characteristics which are hazardous to other road users or damaging to roads is another. It is just possible that the aggressive steel-faced track link of Centurion still has the claimed advantage over rubber-shod tracks in certain extreme types of terrain; but this is a very good example of the need to trade off a marginal aspect of performance for freedom to train. I know very well from experience that the standard of training and morale of tank units in British Army of the Rhine suffered both from mileage restrictions due to the short mean engine life and life between overhauls of Centurion, and from restrictions very necessarily imposed on the tank's use on autobahns and main roads, or in urban terrain.

The second contradiction which faces commanders of all arms, but specially of mechanized forces, stems from the political need to exaggerate the potential enemy's strength. This arises at two levels. Just as it seems psychologically necessary for the people of a nation to have a traditional enemy (3), so the doublethink we just discussed can only be maintained in face of a palpable threat. If a threat did not exist, it would be necessary to invent one.

For this purpose a credible threat will mostly suffice without being too specific in nature or degree. But the moment Congress, Parliament or the Bundestag casts a skeptical eye on the defense budget, every Warsaw Pact soldier has a cubit added to his stature, the sling in his hand becomes a sword and spear, and his fame is blazed abroad. By the same token NATO suddenly discovers it has obsolete equipment and a shortfall in combat manpower.

The junior officer and up-and-coming noncom, urged to keep abreast of affairs as a matter of duty, has all this rammed into his skull by the media. Not surprisingly he starts to wonder whether there is the remotest chance of his army achieving anything at all or of him surviving. Because most men have more physical courage than moral and tend to conform to expected group behavior patterns, leaders have in the past been able to keep men fighting when the odds were hopeless and the fruits of an unlikely victory slight.

One of the lessons to be drawn from the Arab-Israeli wars on the one hand, and from Vietnam and Soviet morale problems in Afghanistan on the other, may well be that modern soldiers are only prepared to fight a losing battle if the survival of their families and homes is patently at stake. When, as is the case with British and United States troops on the European Continent, a limited success is likely to result in the obliteration of their homelands by nuclear exchange while defeat will leave these physically intact, commanders will need every bit of help they can get in building up and sustaining morale.

Sure, this politico-economically inspired gloom is offset by a stream of more encouraging information - or disinformation - flowing down military channels. But I guess this simply adds to the confusion of the men at the sharp end. Not long back (as I write) the air situation over the NATO center produced a

striking example of this doublespeak. In the Congressional hearings on President Reagan's proposal to increase defense spending, civilian and USAF spokesmen from the Pentagon testified to the numerical inferiority of the NATO air forces, to the qualitative inferiority of NATO aircraft (because they were designed to a cost ceiling while the Soviets went ahead and built the best possible machines), and to the relative obsolescence of NATO's fleet of tactical aircraft.

At about the same time British and German published sources (such as London's International Institute of Strategic Studies) were painting a picture of NATO's overall inferiority, but not to the point where the Alliance could not gain temporary local control of tactical airspace. In a British television program on the Soviet Army, based on discussions with United States service personnel, an aircrew officer in the "aggressor" unit of naval aviation quoted figures indicating a NATO superiority of around 15 % in first line aircraft strength (4). He went on to point out the practical demerits of the slightly antiquated Soviet aircraft he was flying (a Mig 19 or 21, I think) and the basic technical limitations of the Mig 23 flown to Japan by a defector.

Now two of these three estimates just have to be wildly out. All are credible on their own; and experience of conflicting evidence in the "objective" estimates of civilian bodies like IISS leaves little reason to suppose that the median view is any sounder than the others. Quite simply, who or what is one to believe?

In face of all these circumstances, confidence becomes even more important to morale than it was in the past. The value of "mission-type control" as practiced by the Bundeswehr (and even more markedly though less consciously by British armor, the Royal Green Jackets and the Brigade of Gurkhas (5)) probably lies just as much in the way it builds confidence as in its direct merits. The armored vehicle crewman needs to have confidence in four things - himself, his equipment, his superiors at least two levels up (probably up to the senior tactical commander) and the feasibility of gaining tactical success. Confidence like this cannot be built on the sand of doublethink and disinformation. It must rest on a tripod of rocks - conviction, dedication and fact.

For the crewman, his equipment represents a large part of that fact. I mentioned earlier - in fact in the context of toilet facilities - the cross-fertilization I sometimes gain from having a multidisciplinary work pattern. At a somewhat less fundamental level I recently translated a paper on sensory testing. The writer's hypothesis was that all testing is sensory because analytical instruments are nothing more nor less than extensions of the senses. I have to admit I was unconvinced; but an approach of this kind does serve to highlight a key principle of biotechnology in general and of sensor technology and control engineering in particular - one which is not lost on the automobile industry's PRs either. **A crewman's station should be seen as an extension of his body - his nervous system and his muscle power.**

We might loosely equate his seat, protective clothing and harness to his sympathetic nervous system. They must help him to adapt to his immediate and instantaneous physical environment by reflexes and unconscious responses. If the crewman's immediate environment starts to obtrude at the conscious level - certainly if it produces problems there - he is distracted from his task. The first two Parts of this book are really about creating an environment in which the crewman's body below the armpits - the part tank designers

always want to cut off - can provide and sustain optimum support for his head and hands.

We are far more closely concerned, though, with the **somatic nervous system** in which sensory stimuli are perceived by receptors, then transmitted to and processed and stored by the cerebral cortex; and in which the control side of the system transmits commands to the motor nerves. I now want to pan in on two principles of the functioning of this system in man which are fundamental to success at the man-machine interface. These principles are, I suspect, far too little appreciated - let alone understood - outside the circles of applied and experimental psychology, neurology and cybernetics. We shall look at these, along with others more widely accepted, in later chapters; but they are worth a preliminary general glance here. The principles I mean are **redundancy** and **closed loop control** (crystallized in the term **feedback**).

Subjective experience and massive scientific evidence combine to indicate that our upper brain requires a challenge. We are none too good at solving computerlike problems at the conscious level. We ramify simple issues with associations and make elementary errors through what we sense as boredom. We only tackle problems effectively and arrive at a conclusion in which we have confidence if we are presented either with too little information or with too much. We may delight in enigmas, where information is minimal, obscure or even misleading, as a springboard for mental gymnastics. But when we have to solve a practical problem in short order, we feel lack of information to be frustrating. Sometimes, thanks to our brain's ultrasophisticated switching (synaptic) system, we are able to "pull something out of the bag," specially in a crisis calling for instant response. At other times, though, we bog down or confidently execute an erroneous response. Evidently deliberate denial or distortion of information makes little sense in the kind of problem-solving an armored vehicle crew is faced with.

So there is a need to provide surplus or **"redundant"** information which the brain can monitor and some of which it can reject. Conscious rejection of redundant information looks to be a necessary stage in the efficient, goal-oriented processing of a problem and hence in the selection and confident execution of an appropriate solution. The designer's aim should be to provide the buttoned-up crew not just with the essential minimum of information but as nearly as possible with the amount of information - relevant or otherwise - which they would be receiving if they were not boxed in. This will aid not only their efficiency but their morale, minimizing the feeling of confinement which, as the term claustrophobia signifies, engenders or at least fosters fear.

So **feedback** is doubly important. It closes the control loop and thus underlies most operations a crew performs from steering, through corrections of fire, to radio communication. And it maintains their natural environment of information inputs. Most important of all, and most difficult to achieve as sophistication mounts, is the kind of feedback summed up in the expression "seat-of-the-pants flying." Visual and auditory feedback can be maintained by indirect systems - indeed they have to be. The problem is to provide haptic feedback.

The driver has a position which does not voluntarily change relative to the hull; he still physically undergoes - albeit in modified form - the translational and rotational accelerations of the vehicle's movement. He probably still gets enough tactile inputs, provided that he is getting visual inputs at the redundancy level from his vision system. With the engine compartment sealed off, he may lack the normal auditory inputs, notably the response of the engine to the gas pedal. Experience with driving simulators, in which appropriate noises can be fed in or withheld, suggests that it may pay to pick up power train and track noise and feed it, suitably attenuated and cleaned

up, into the headset of the crew member who is driving. For cross-country movement all crew members in fact need this noise to help them "ride" their vehicle. This auditory input will increase in importance with usable cross-country speed.

The function of feedback in nonbiological servo systems is to provide a stabilizing or correcting signal - to answer the question "Have I done it right?" By contrast the main question the human operator is apt to ask is "Has it done what I told it to?" This is what makes auditory input important for driving. Additionally it is the strongest remaining argument against slaving gunnery functions. Nobody who has not switched from a direct system to an equivalent slaved one (6) can begin to appreciate the sense of helplessness imbued by the lack of haptic and auditory stimuli. A "gun position indicator" which you can look at afterwards is difficult to interpret and likely just to spark the further question "Is the indicator working?" A positive audio (and maybe visual) indication of lineup is much better. But again it may well pay to pick up the noise of weapon pod movements and feed them into the crew's headsets. I guess the complexities of manual lineup - that is a lineup mode switch plus operation of the traverse or elevation controller - and even systematic tactile feedback through the controller (as in some powered steerings) are worth looking at.

Speaking of **complexity** - another key factor in the soldier's confidence in his equipment and hence in his morale - an interesting situation seems to be arising. The Germans, with a relatively short-term conscript army, are very relaxed about complexity. They see advanced technology as equating to ease of operation, and confidently envision crewing even Gepard (their gun-based self-propelled air defense weapon system) with reservists. The British stick solidly (Or did I drop a "t" there?) to their "simple soldier" line. The Americans, though still (at the time of writing) with all-volunteer forces, are admitting to considerable difficulty in operation and maintenance of air, land and sea weapon systems alike - and this with some established, even obsolescent systems as well as with new ones. Their officers complain of an excess of "low education" personnel. But one suspects that the widespread and mounting rejection of technology and the hard sciences by the Anglo-Saxon culture and education system is undermining even the traditional technical awareness of the American population.

This is why I laid so much stress in earlier chapters (notably Chapter 11) on ease of operation and crew servicing. I have to admit, though, that armed forces cannot exploit advanced technology unless they can recruit, by drafting or otherwise, enough good personnel at the technician level. I say "personnel" advisedly, for a high proportion may well be women. The British services have never had much problem over the quality and quantity of technicians, however great their difficulties over the intellectual quality of conscript and volunteer combat soldiers. The British situation imposes limitations but does offer a basis for a design philosophy in which the balance between complexity and ease of operation sets the crew the right level of challenge.

I hope the above will suffice to indicate that a number of factors normally absent or of little significance in control engineering may be important, critical even, in the armored vehicle field. Much evidence from early work on the selection of controllers for antitank guided missile systems and on prediction of their performance under battle stress suggests that the controller of a manual command link system feels he is "right out there flyin' the missile." There are many like myself who find intense excitement in the exercise of control skills. A system that handles and responds like an

extension of ourselves breaks for us the bounds of our individuality, much as sex does but at a level less fraught with emotional and cultural overtones. Again as with sex, the key to satisfaction lies in a two-way act of unconscious communication. Nobody questions that achievement of a satisfying man/machine interface is a key design aim in automobiles; it sells them. Or in aircraft; it makes them safer to fly. I suggest it is likewise a major goal in armored vehicle design. It leads to high achieved performance (Chapter 2) and plays a leading part in attaining and sustaining high morale.

Notes

1 I use the Bundeswehr's own translation of their terms. We will look at this doctrine more fully in Chapter 20. See Bibliography.

2 Chapter 24.

3 If toys and children's games are anything to go by, still our WWII enemies for the British and, I suspect, the American public.

4 Unfortunately I had no reason to suppose that this program (broadcast in April 1981) would be any less superficial or woolly than most TV documentaries, so I had not prepared to take notes. In contrast to the aviators, the members of the US Army's "aggressor" formation, supported by a Soviet tank officer who had defected, gave a very sound assessment of M60A3 and T72. ("Aggressor" - a trials unit or formation organized and trained on Soviet lines, and equipped as far as possible with Soviet hardware; also known as "opposition" or "threat" units/formations.)

5 The Royal Green Jackets is the infantry regiment merged from the rifle regiments formed from the "Experimental Corps of Riflemen." This corps formed the "inner nucleus", revolutionary in discipline, dress and tactics alike, of the Light Division which General Sir John Moore formed and took to the (Iberian) Peninsula in 1804. The Brigade of Gurkhas, now part of the British (metropolitan) Army, has a similar tradition.

6 As in my day from the Centurion commander's station with its override controls to the commander's subturret of Conqueror. By contrast one adapted quickly to the contrarotating cupola of later Centurions because of the accelerations imparted to the commander's body through the seat and the turret basket.

CHAPTER 15

Survivability and "Restorability"

Conventionally-minded soldiers and many without military experience may take exception to talk of containing fear. The infantryman is under the extreme constraint of his hesitancy being obvious to all. But armored vehicle crewmen have considerable scope for less than ideal behavior under fire of kinds that may not be evident even to other members of their crew. Tank platoon and company commanders with combat experience are all too familiar with "back marking" and taking up what one might call "positions of non-observation." It is not always easy for the crew commander on the spot, let alone the platoon commander at the end of the radio, to tell whether a malfunction is genuine, deliberately induced or simply feigned. Again one has seen and heard of tanks mysteriously veering off lanes through friendly minefields at the beginning of an attack.

If crews are to conduct themselves bravely and perform efficiently under fire, it is not enough for them to have more physical courage than moral. They need what one might call **"positive morale"** - a genuine and sustained resolve to contribute to the battle. Nobody would dispute that leadership plays the major part in achieving this goal. But leadership is not enough. Like most of its kind, the problem has to be tackled from both ends. Armored vehicles must not only instil confidence by their performance but help contain fear by their general and biotechnological design.

Hitherto the state of the art has more or less allowed the user to duck the very uncomfortable question of what armor is for. But present realities and the technological possibilities of the nineties force him not just to ask this question but to give a clear answer to it. The real goal may be system survivability, crew survival or what I shall term **"restorability"** of the crew-vehicle system (1).

System survivability means the ability of the total crew-vehicle system to go on fighting after sustaining a hit. To justify itself at all, the system must be able to survive attack from nonspecialized weapon systems; it should have a good chance of surviving attack from secondary dedicated systems like individual and crew served weapons. But I for one see little chance of its sustaining a fair hit from a primary antiarmor weapon system and remaining fit to fight. Not only is the power of kinetic energy attack keeping ahead of feasible passive armor systems. The advent of the attack helicopter and of indirect fire antiarmor weapons with large angles of descent (like Copperhead) collapses the concept of the horizontal frontal arc on which passive protection

against dedicated attack is based. Additionally eighties attack helicopters (likewise of course fixed-wing aircraft) can carry guided missiles with an overwhelming power of explosive attack.

As long as tanks had a reasonably high system survivability, it made sense to pay special attention to crew survival. Indeed the ability to get a crew and their weapons across a fire-swept zone was fundamental to the concept "tank." Likewise it made sense for the crew to fight on, maybe immobilized, maybe reduced to emergency systems, while their tank was progressively shot away round them. Now, even if the armor "defeats" the attack, the vehicle is unlikely to be able to fire effectively after a fair strike from a primary system. Stunning of the crew, subsidiary damage and sheer confusion will almost certainly leave it a sitting target for a coup de grace. In these terms I personally - and this has to be a subjective value judgment - do not think it makes either military or ethical sense to armor specifically for crew survival when the crew of major armored vehicles are mostly fighting alongside men on their feet and the crews of lightly protected armored vehicles and helicopters.

This statement is, I suggest, inherently valid and logical in its own reference framework. But before fellow tankers acuse me of armchair disloyalty, let me hasten to contradict it. One of the key factors in man's ability to cope with fear is the chance of an "out." As long as this chance is genuine, that is based on physical reality, it does not seem to matter how remote it is. We talk about brave men "facing certain death", but this is not strictly accurate. We in fact place *kamikaze* pilots and mountaineers or explorers like Petty Officer Evans (2) in a special category as heroic suicides. The rest may face a ninety nine percent chance of death and know this. But it is, I suggest, hope - awareness of the one percent chance of survival - that enables them to overcome their fear and perform their feats of valor. We shall be looking at more detailed implications of this basic need for an "out" in the next chapter. For the moment I want to pursue the point in relation to the total crew-vehicle system.

Even in a conventional turreted tank, it is the armament, most probably the fire control system, which is likely to be crippled by the shock accelerations of an attack which the armor defeats. In what looks to be the most probable configuration for most future armored vehicle weapon platforms (3) - the external gun (pls 3, page 21, and 4, page 38) - the armament and its associated sensors are by far the most likely elements to be hit. In either event the vehicle may well be able to drive away if at least the driver remains conscious and there is no fire. Or it can be dragged - "recovered." With the external gun there is no reason why a hit on the armament pod should even stun the crew or affect mobility. So, with apologies for introducing a new buzzword, we can go over to the concept of **restorability** as a substitute for **system survivability** in face of the primary specialized attack.

Fact is this revised philosophy of direct protection, running in a *troika* with a pronounced switch of emphasis to indirect protection (hit avoidance) and maybe to active protection (countermeasures), has a great deal to offer besides boosting crew morale. So let me digress a little. The latest American thinking (4) favors a balance in which passive protection, hit avoidance and countermeasures make roughly equal contributions to survivability (fig. 12b). I am less sanguine about the ability of active protection to do more than raise the ante and produce the rather inconclusive situation I have described elsewhere as "countermeasures to the nth" (5). At this time indirect protection looks to be a highly promising approach against surface-to-surface attack. But this equilibrium could be upset by an automatic target acquisition system (4, 5), while indirect fire, antiarmor weapon systems with high angles of

descent, and downward-looking modes of attack such as self-forging fragments (SFF) put a rather different aspect on hit avoidance (5).

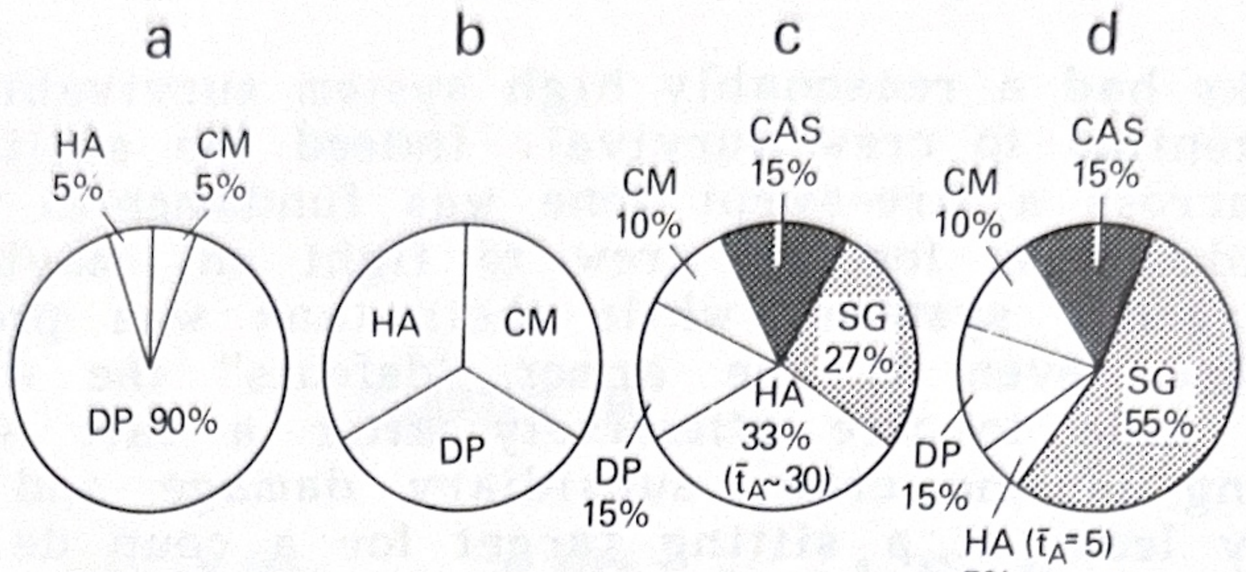


Figure 12. The survivability gap

CAS = freak casualties
CM = countermeasures
DP = direct protection (passive, dynamic armor)
HA = hit avoidance ($\bar{t}_A$ = mean acquisition time in seconds)
SG = survivability gap

a. 70s/80s estimate (Bradley)*
b. Trend forecast (Bradley)*
c. 90s forecast with evolutionary improvement of fire control, $\bar{t}_A$ = 30 (Simpkin)*
d. 90s forecast with automatic target acquisition system, $\bar{t}_A$ = 5 (Simpkin)*

(*See Bibliography, **Armor**)

Extending the definition of system survivability to include restorability (fig 12c) gives the survivability cake a much healthier look. What is more, designing for restorability opens up a whole bunch of options which are highly interesting in their own right. Suppose the vehicle of figure 1 (page 20) to be redesigned so that it consists of a frame on which the running gear is mounted and which carries the front half of the vehicle (engine and crew compartment) in the form of a pod (fig 13). This pod could be given a very high level of protection over large horizontal and vertical arcs. Suppose that the pod also contains a high proportion, say 75 %, of the electronics (which represent around 60 % of unit cost) and as much as possible of the power electrics; that it and the running gear make up two thirds of the total weight; and that the real financial value of a trained crew is half that of the vehicle (6). Then the restorable portion of the total crew-vehicle system adds up to some 85 % of the system unit cost slice. Also, the "expendable" portion of the hardware of an MLC40 vehicle would weigh 12.0 to 12.5 t, the kind of figure that looks right for the dedicated logistic payloads we explored in Chapters 12 and 13.

Once one has accepted the ideas of dedicated swop bodies for logistic vehicles and magazine exchange, it is no great step to think in terms of "swop bodies" for armored vehicles. Instead of exchanging a spent magazine or replacing one damaged or jettisoned in combat, a complete armament module is swopped or replaced. This would get a weapon platform which had suffered a severe F kill back into business in a matter of minutes - and that is one side of the restorability coin.

Figure 13. The pod concept (overleaf)

a. This exploded schematic indicates the principle of pod/modular construction associated with the concept of "restorability." A U-shaped frame (1) carries the modules and provides stiffness over the rear half of the vehicle. The running gear (2) is shown purely schematically, the only relevant point being the front sprocket. The main permanent module is the automotive/crew pod (3 and fig 14). If technologically and/or logistically preferable, these permanent elements, (1), (2) and (3), could be integrated into a single unit. The interface panel (4), supported on the forward cross member of the frame (1), simply provides for physical and electronic matching of the automotive/crew pod (3) and the functional module (5A, 5B etc). The two major forms of functional module - the external gun configuration (5A) and the "armored box" (5B) are indicated, the latter in squad IFV form. Other variants would be broadly based on one of these functional module configurations.

b. An artist's impression of the main external gun tank destroyer or fire support tank.

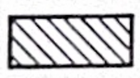
c. An artist's impression of the squad IFV.

(Note. These are concept schematics which only take account of **leading** design considerations at the level of first approximation. The running gear is scaled from MARDER, pl 5.)

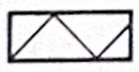
Figure 14. Automotive/crew pod (overleaf)

Schematic plan view (a) and section approximately through commander's station (b) of crew/automotive pod (fig 13, 3).

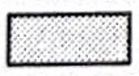
(key)



Principal metallic elements of integrated compound armor system



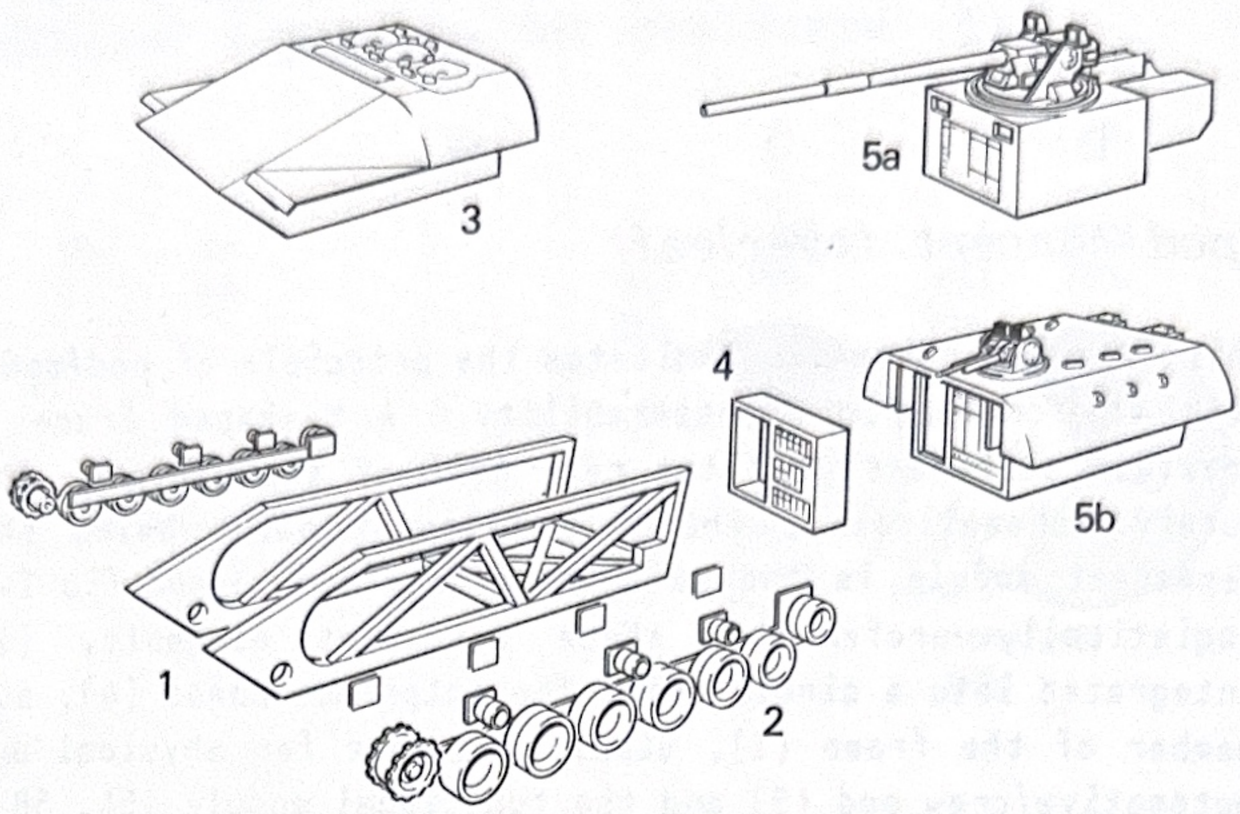
Compound armor array



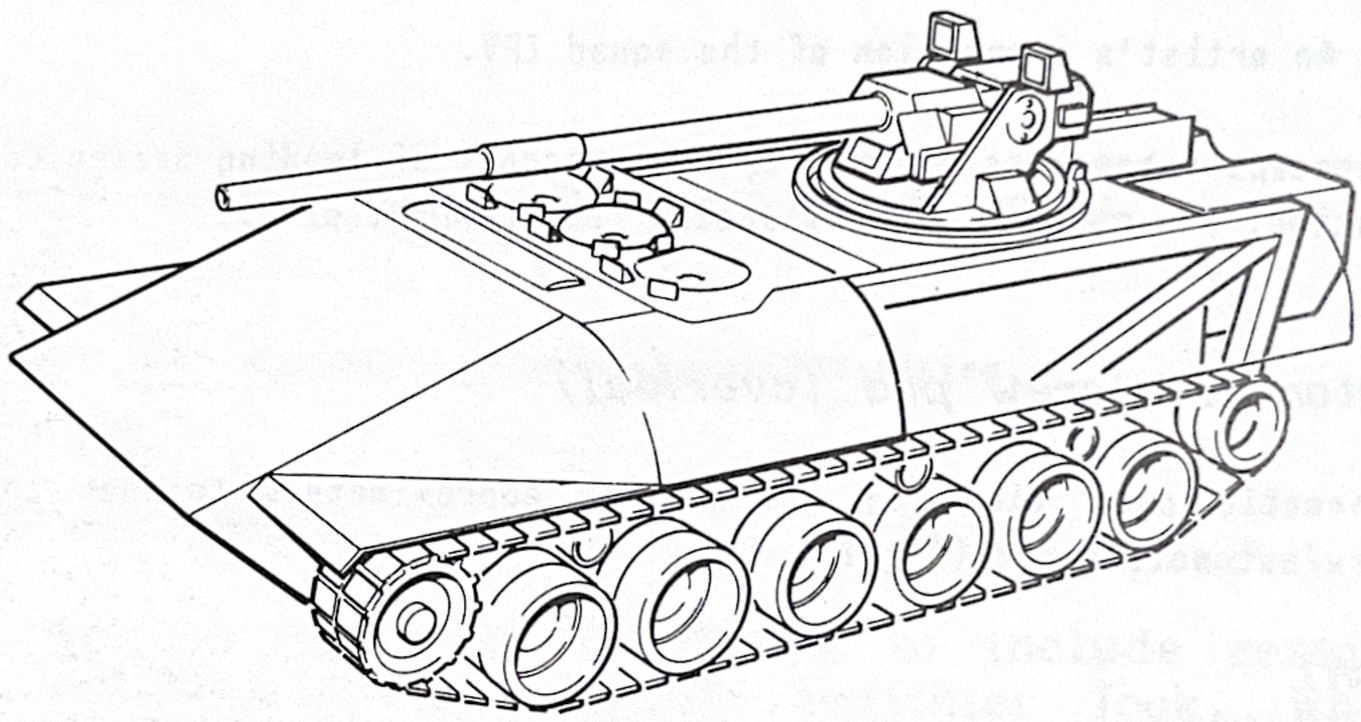
Boronated plastic liner

Electrical/electronic packs

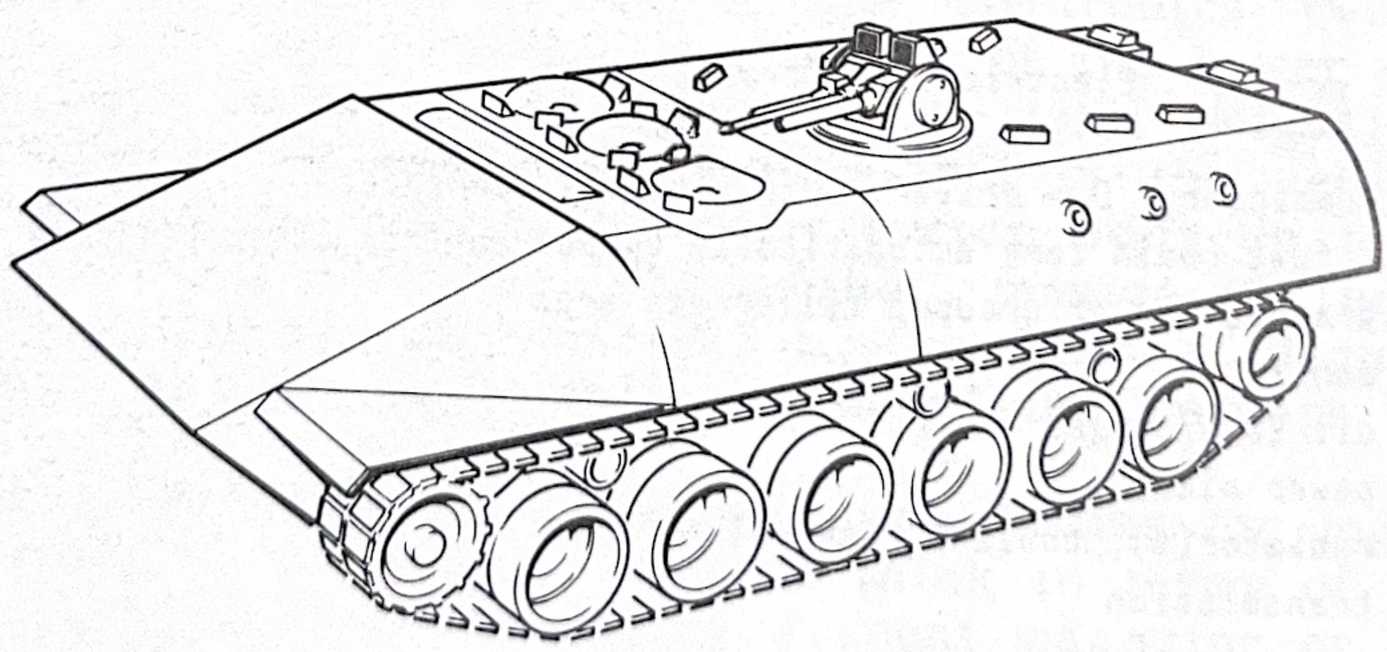
C = commander, D = driver, D/C = deputy commander
F-F = fuel (main tank automatically topped up from other tanks in sponsons etc)
G = armored lid of grouped filler etc area
M = monitor
O = oil tank/cooler
P = power plant
R = radiator(s), coolant reservoir
T = transmission



(a)

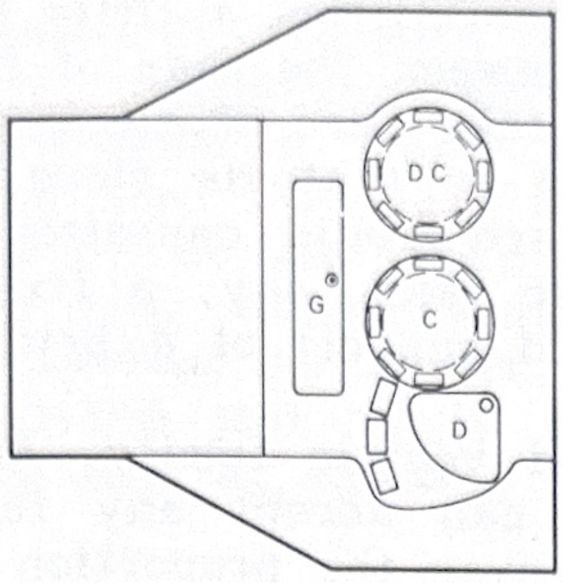


(b)

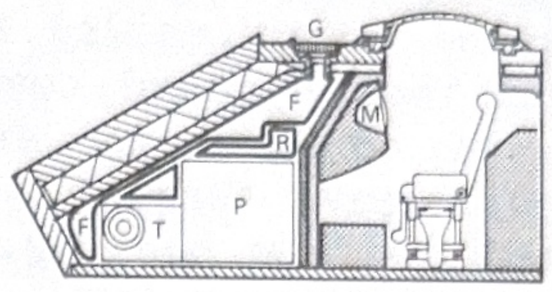


(c)

(a)



(b)



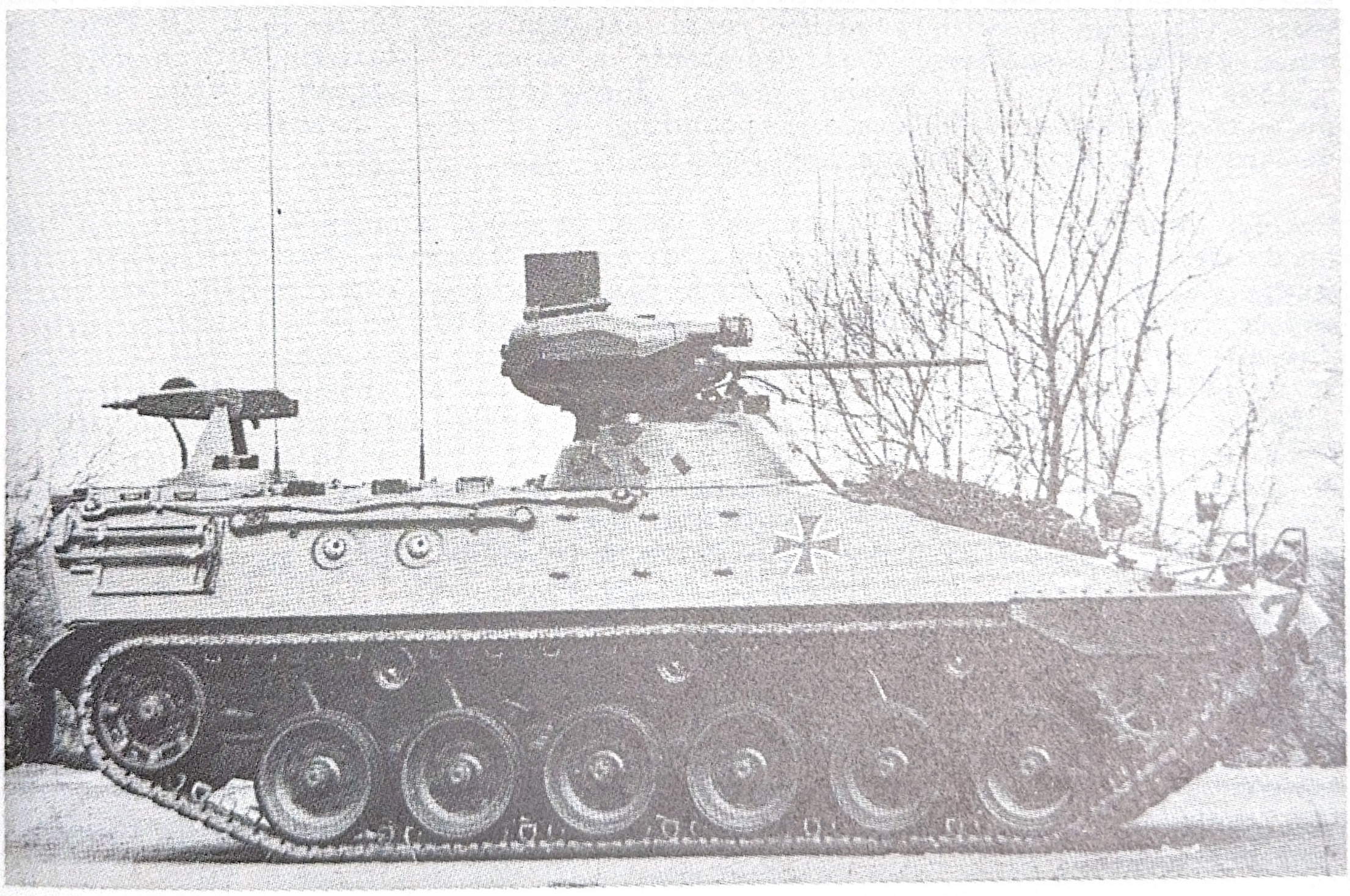


Plate 5. The MARDER infantry fighting vehicle

The German Marder dedicated infantry fighting vehicle (IFV). This hull and running gear has been used as the basic model for the concept studies of figures 13 and 14. Marder weighs 26 t (rather under MLC30) but is a high-volume, low-density design. A versatile hull/pod with an integrated frontal compound armor system could be expected to lead to a battle weight around MLC40 for these dimensions.

Let us now flip the coin and explore the possibilities a little further. Envision an interface panel (fig 13, 4) interposed between the rear of the crew pod and the functional (replaceable) module (5) to take care of electronic and physical differences; the on-board computer arranged so that its store of programs and data can be changed by switching standard audio cassettes; maybe even a longitudinal sleeve through the front pod to take, say, a fixed gun tube with its intermediate tube bearing, or the forward support of a bridge.

Then we have a completely flexible armored vehicle family. Any basic vehicle (frame, running gear and automotive/pod) can accept any functional module. The balance of TDs, FSTs, IFVs, CSVs and even the proportion of, say, AVLBs, can be changed very rapidly in the field. This concept, sometimes referred to as **"task configuration"**, is evidently even better suited to the Swedish design concept of articulated armored vehicles (pl 4, page 38), although their present ideas on the contents of the two halves - currently based on eighties technology - would need a rethink. The clue lies in electronic data processing and transmission, above all in the adoption of **slaving**.

I next want to look at the recovery and casualty evacuation roles of the platoon CSV, carrying a medical orderly and an armament technician (also trained in battle recovery) and fitted (probably at the rear covered by CCTV) with the male half of a "docking" type link with other vehicles. We might begin by using an analogy to justify these needs. Soviet and Western analyses based on the exposure to chemical attack of trained, warned and protected troops (7) come up with a rather consistent figure of 10 to 15 % fatalities or other serious casualties. This represents a kind of statistically unavoidable residue made up of human error, indiscipline, communications failure, protective subsystem failure, compounding of effects, accidental and battle damage to protective clothing and the like.

Nuclear warfare apart, I have not seen similar analyses of personal or hardware casualties from conventional fire. But I would strongly suspect this figure of 10 to 15 % to be one which can be widely extrapolated. One might expect it to apply, for instance, to the "restorable" (that is nonexpendable) elements of the vehicles proposed above, including their crews (see also fig. 3c). Additionally there is the particular hazard of track-cutting mines or minelets. If the mines are covered by fire it makes sense to pull the vehicle back behind cover. I guess we are looking at a pattern in which up to 25 % of battle-damaged vehicles will be unable to motor to safety and will require assistance. This in no way invalidates the "restorability" concept, because under it most of this 25 % can then be back in action within minutes.

To avoid drawing lethal fire and/or being overrun by the attacker, recovery will need to be carried out very rapidly behind smoke. The screen from both vehicles' smoke cups can be deepened by the CSV's 76 mm gun. With a "docking" link, there should be no need for anybody to dismount. Where this is so, dragging the vehicle behind cover is almost certainly the safest immediate action unless fire, overturning or such have already unhorsed the crew. In that event they are picked up through the CSV's rear doors and the damaged vehicle is abandoned.

Once the damaged vehicle is defiladed from direct fire, there should be no problem in getting it mobile enough to motor back to the technical and emergency resupply sections of the service platoon, located a short distance behind company headquarters (Chapter 13). The vehicle could for instance be short-tracked, or a temporary quick-fit overlength track link could be provided.

Crew casualties would be replaced by one or both of the relief crewmen on the CSV. Extraction of unconscious and dead men from crew stations should be easier in a vehicle with a single level crew compartment or pod than in a turreted tank. But the CSV must carry a suitable harness and the medical orderly be trained in its use. Once casualties are on a stretcher (if needs be) and in the CSV's rear compartment, they can stay there until the CSV can marry up with a casevac helicopter. I do not envision a conventional armored ambulance; if required this would be a member of the light "workhorse" APC family, presumably held at company level.

If there is such a thing as a "human factor", survival has to be key one in anybody's language. This is not the place to explore all the positive innovations that the principle of **restorability** and its application to design open up. I am convinced though that it offers a substantial reduction in the physical, tactical and moral effect of crew casualties and battle-damaged vehicles alike.

Notes

1 Since recoverability, repairability and reclaimability all have specific assigned meanings in British, United States or NATO logistic jargon, I am forced to coin a new buzzword.

2 Who walked out of the tent into the snow as Captain Scott's expedition to the South Pole approached its climax of disaster.

3 Since Sweden and now the United States are actively pursuing it.

4 See Bibliography, under **Armor**, Clifford Bradley, also myself.

5 **Antitank**, Chapters 4, 11, 12, 16 and 17.

6 This figure is available for aircrew but is seldom presented for ground combat forces. I have taken a conservative figure because, if my argument holds with this, it is strengthened by any higher one.

7 Personal protection only.

CHAPTER 16

Escape Facilities and Crew Casualties

The concept of an automotive/crew pod of low vulnerability, an openwork frame and running gear which is unlikely to suffer much damage (except from a mine) even if hit, and an interchangeable functional module can offer a valuable complement to system survivability. Certainly "instant" recovery will succeed in a proportion of cases in which the crew cannot motor their vehicle out of danger. If survivability proper, "restorability" (Chapter 15) and recovery together achieve a real system survival rate of 75 % in defense, they would have a rather remarkable effect. But even then the crew, or the survivors of it, still have to abandon their vehicle on one in four occasions of battle damage or accident.

Because even the slenderest hope of personal survival is so fundamental to morale, everything possible must be done to provide an "out" in these situations too. This is doubly so when capture is no longer a soft if unattractive option but a truly daunting prospect. Soviet treatment of German WWII prisoners, the nonrepatriation of many and the disappearance of more, hold out little enough hope for those who fall into Warsaw Pact hands. And the kind of counter-jihad scenario I discussed in *Antitank* - in the view of many the most probable one for the nineties - leads a prisoner of war to expect nothing but a quick death at best, more likely a lingering one preceded by torture and mutilation.

So we have to address the question of personal survival of armored vehicle crew at three levels. The first is to provide an unhorsed and uninjured crew with the best possible chance of evasion and escape. We already looked in some detail at the provision of a survival pack in our discussion of external stowage (pages 24-25). The only point that needs reemphasizing here is the importance of speed in getting away from the vehicle.

This links directly, though, to the second aspect of the problem. A crewman who has not suffered serious injury must be able to **get out of the vehicle** quickly and easily whatever its attitude, even if his normal hatch is jammed by battle damage or blocked, as it might be on an overturned vehicle. This means that each crewman must have **three** escape routes -

his normal way of mounting and dismounting

access to another crewman's hatch if his own is jammed

access to a hatch in the side or belly in case the vehicle is upside down or under fire from HE shell or small arms.

We might do well to consider this last point now, since it calls for a dedicated design feature and has little direct effect on the layout and design of crew stations - apart of course from the need for all crewmen to be able to reach any special escape hatch. Many tanks have had **belly hatches**. This is the best way of catering for the case of a vehicle resting on its side with the normal hatches against, say, a bank, or on its roof. Theoretically it also allows the crew to dismount under when the vehicle is the right way up. Here though it has two major drawbacks.

If the tank is on a soft surface with even normal track sinkage, there may not be room to get out. The second disadvantage applies to a conventional turreted tank rather than to the single level or pod configurations envisioned in this book. It is simply that the turret crew, specially the commander, take far too long to get to a hatch under the driver's seat; if the turret is jammed, some or all of them may not be able to reach it at all. Additionally, to the extent that attack by large conventional track-cutting mines (specially "bar" or "coffin" mines) remains a serious threat, a belly hatch is an area of weakness within the mine's primary blast cone.

In the layouts we are considering, a far better approach is to jettison the magazine or the functional module, as the case may be. The access door for secondary ammunition (page 82), or its equivalent, then provides a means of escape which is likely to be usable when the main hatches are blocked and reasonably likely to provide cover from fire (1). If the functional module is proud of the automotive/crew pod roof, or in a "one-piece" design with any form of external gun mounting, there should be room to escape through the normal hatches if the vehicle is upside down or on its side with the mounting against a bank or such. The key points here are maybe that any mechanical or hydraulic jettison mechanism must be positive in action; and that both it and a backup system of jettison charges must be powerful enough to discard the magazine or armament module in any attitude where the vehicle's weight is not resting on it.

My own experience and tank casualty statistics indicate, however, that the second requirement I postulated - the ability to escape through another crewman's hatch - is far more important at both practical and psychological levels than the provision of an escape hatch as such. The jamming of a hatch was not infrequent in face of medium and heavy artillery fire with conventional HE shell. The various forms of threat to the vehicle roof which are likely to be around in the nineties make this risk a far higher one. Certainty of access to a second hatch imposes significant design constraints; indeed it forms the basis of a whole philosophy of crew compartment design.

Once machinegun subturrets, hull gunners and the like gave way to a clean V-front, the driver of a turreted tank always was out on his own. In most tanks he had a removable or collapsible seat back, which provided a passage between driver's compartment and turret over traverse arcs totaling, say, 180 to 240°. This access was by no means assured. It was apt to be blocked by the gunner's station over most of one of the forward quadrants; and the pocket between the driver's hatch and the underside of the mantlet resulted in a high risk of a single hit, even an HE shell, jamming both driver's hatch and turret ring. Whence the belly hatch, which at least the driver could reasonably hope to use.

In tanks of the true "main battle tank" generation like Centurion, Leopard 1, M60 (excluding A2) and T54/55 the turret crew were in what amounted to a single compartment. They could all talk to one another (in the standby state), touch one another and change stations, although the latter might involve minor stripping (of the spent case basket, for instance) if the gun was jammed at certain points in its elevation arc. I already commented on Centurion's high habitability (page 38, pl 4); ease of access to either turret hatch goes with this. Some modern tanks retain this **proximity of turret crew**, at least in some degree. It is a key factor in morale both during waiting periods and in battle. We considered it in Chapter 4 and will return to it later in this chapter and in subsequent ones. Evidently the principle should if possible extend to the driver as well.

Contrariwise the "compact" turret of M60A2 (pl 1, page 10) isolates all four crew members from one another when they are in their normal stations, although there is some scope for getting together underneath the gun. A more striking example of segregation was the British heavy tank, Conqueror (pl 6). Here, as in M60A2, each crew member had his hatch; but in the prototypes the gunner could not get to any other hatch. In production vehicles too, movement between the driver's and loader's stations was only possible at certain rather limited relative positions of hull and main turret. My recall is that access between main turret and commander's subturret was possible only in one relative position of the subturret and that even this called for minor stripping.

Plate 6. CONQUEROR commander's sub-turret

This view of the British Conqueror heavy tank well illustrates both the commander's isolation and the orientation problem he faces. No wonder he looks baffled!

The Conqueror gunner was isolated by a transparent plastic shield intended to protect him against injury from cartridge cases during loading and ejection and against fumes. In the prototypes the shield was rigid and fixed. This problem was easily resolved by hinging the shield vertically to form three panels and securing it by sliding bolts. The commander's position was a less happy one, and not only from the viewpoint of escape if his hatch jammed - as this early British lift-and-turn lid was all too apt to do even without encouragement from the opposition. His communication with the driver was dependent on a circuit passing through two sets of slip rings. If the circuit was interrupted between main turret and hull, the commander could still pass messages through the loader, who could then shout to the driver or, if the main turret was in the right position, kick or tug him in the time-honored manner (2). The most unreliable point of the intercom, though, was between commander's and main turrets. If a fault here also deprived the commander of his override facilities, he was just about helpless when the main engine was running.

With the control console layout I postulated, or with commander and deputy commander/gunner seated in separate stations alongside the driver and each other, voice and physical contact between stations is evidently much easier. The choice between a two-man console and separate stations is a nice one but not relevant here. In any event commander and deputy commander have an alternative escape hatch via each other's hatches unless both are jammed; and as I envision it the driver should be able to get across to the center station or console in most if not all positions of traverse.

Nonetheless, quite apart from the escape problem, the advantages in design and habitability of not rotating the commander and deputy commander are very great. One must seriously consider fixing them for-and-aft and providing them with good vision over, say, the forward 270° arc and access to the driver's rear vision CCTV via their fixed monitors in addition to a processed signal from the bank of sensors at the highest point of the vehicle. I personally believe this is the long-term solution, but I am not sure whether the nineties user will accept it. His key contribution will be to accept and master slaving, if needs be himself remaining free to rotate. His successors, to whom slaving will be old hat, may well be able to cope with a body position completely fixed relative to the hull.

So far we have looked at escape from a damaged vehicle by unhurt or slighly injured men. A factor of maybe greater significance still in crew morale is the ease of administering first aid to a severely wounded man in his crew station and of extricating a helpless or unconscious casualty from it. To this one might add the importance to the whole crew, most of all to the crew commander who inevitably feels himself responsible, of being able to comfort a dying comrade.

I make no apology for reemphasizing yet again, in this graver context, the reality of the need for crew members to be able to touch one another, to pass one another candy, cigarettes and food or drink, and to converse normally when the vehicle is in the standby state. Those who have not been privileged to serve with troops may easily suppose soldiers to be brutish and regard them as a kind of "bionic" artifact. Unfortunately and far less excusably, a minority of officers are all too apt to do the same when it suits their purpose (3). Again, civilians may readily forget that armored vehicle crews are unique in having to live for long periods based on, maybe buttoned up in the cramped and specialized environment in which they fight. The phrase "human factors" means just what it says. There is far more to it than biometry and biotechnology, more even than the aspects of psychology commonly supposed to

have a bearing. Analysts and designers who ignore the whole man may produce highly efficient fighting machines; but they are unlikely to produce machines in which men win battles.

To get a slant on the problem of extricating severely wounded men, we might go back to a conventional turreted tank with the driver located centrally in the hull front and the gunner in front of the commander with no hatch of his own (4). Suppose that a kinetic energy penetrator has glanced off the driver's periscope, pushing it back into the driver's face and jamming the hatch, and then turned upwards under the mantlet and penetrated, jamming the gun in elevation, putting the powered mounting out of action and causing severe injuries from spall and fragments to the side of the gunner's head along with heavily bleeding lacerations to his neck and shoulders. Commander and loader are unhurt.

Note first that tanks of this configuration and vintage (5) have no override or emergency driving facility, so there is no way the tank can be moved behind cover immediately. The ideal commander would first apply dressings to the gunner to control bleeding, administer morphine and mark the man's forehead accordingly. Because the gunner's seat provides no lateral or head support, the commander will have to remove the seat back. He will then be tied to nursing the gunner's head and shoulders in his lap. Suppose he then reaches the main emergency traverse switch, tries his override controller and finds it works. Guided by the loader, he traverses until the back of the driver's seat is clear.

While the commander tries the radio to call for help, the loader collapses the seat backwards and finds the driver semisupine and unconscious but with no apparent lesions except contusion of the forehead and face. The loader pulls the driver first into the supine position, then backwards onto the floor of his own station, and examines him. He reports to the commander and is instructed to drive the tank into cover. The loader turns the driver into the recovery position, tucking his legs into the turret basket, and slides feet first into the driver's position.

He reports to the commander on the intercom, which is still working, that the hatch is completely jammed, he has no vision and damage is such that he cannot fit the spare periscope head. Because he is nursing the gunner, the commander cannot turn in his station; so having checked visually that the driver is fully within the turret, he traverses to 6 o'clock and orders high reverse. He successfully guides the tank behind cover and makes a rendezvous with the armored ambulance.

The ambulance crew can now get at the driver, splint him if needs be, and get him out on a straight lift through the loader's hatch. His risk of being further injured came earlier when he was being dragged backwards from his seat. With the gun jammed in elevation, the gunner cannot be reached or evacuated over it. Having received help and advice from the ambulance crew in immobilizing the gunner's head and neck, the commander slides down so that he is clear of his hatch and pushes the gunner up over his body until the ambulance crew can reach him. Even then they are faced with a very awkward angled lift. The gunner dies in the ambulance because of the delay in immobilizing him and from loss of blood aggravated during his extrication.

The lessons from the scenario stand out so sharply that we can apply them direct to the "three-in-line" crew layout on which this book is based -

> Override driving controls are essential to get a crippled vehicle to safety (even if there were not many other good reasons for them).

In a vehicle with a traversing control console or separate traversing stations, the driver should have an emergency facility for bringing the console or center station to a point at which he can get at the crewman/men in it - and himself get through to it.

Seats must provide full support, including lateral support, from thighs to neck; again there are many reasons for this besides protection of casualties.

Every crewman should have a hatch which allows him to be lifted out on a straight pull and a second hatch near enough for him to be extricated by a one-stage oblique lift. A loop or sling on the clothing (page 51), as for instance in the Swedish experimental tank suit, is a key aid to this.

Inflatable splints are a must for armored vehicle first aid kits. It may also be worthwhile carrying a larger quickly inflatable bag (of the type developed to constrain persons in auto accidents) which would hold a helpless man firmly in his seat while the vehicle was moved to a safe place where he could be extricated and treated.

Speed in getting the casualty to a point where he can be safely extricated and properly treated is paramount. The presence of a platoon CSV with some medical facilities is likely to be a real lifesaver.

A less clear-cut matter is the issue to crews of morphine or some equally quick and potent painkiller. Whatever is used must be administered by injection, not orally. This can be (and is in some armies) done with the same type of "autoject" device used for self-administration of atropine as a nerve gas antidote. There is no question that lay administration of a substantial dose of a powerful drug may hamper subsequent treatment, even to the point of loss of life in a severely wounded man. By contrast, quite apart from the impossibility of applying first aid or immobilization to a man who has lost control of himself through trauma and pain, the casualty's behavior may endanger the whole crew and their vehicle. This is to my mind the clinching argument - though I would be the first to concede that its physiological effects and its social connotations make morphine anything but ideal.

Even the minority of officers who are apt to forget about their men's finer feelings realize that the way fatalities are handled is critical to morale. Most vehicle commanders are aware, from instinct if not from experience, of the importance for the rest of getting a fatally injured man out of an armored vehicle and into a treatment situation before he dies. This adds force to what I said above about ease of extrication. At the other extreme a disrupted vehicle with its crew severely burned and/or largely dismembered is something other crews are best kept away from. This is a situation in which the natural wish of a group to look after its own dead has to be overridden because of the risk of loss of nerve.

There are two cases, though, which need to be considered. They do not bear directly on performance or other design features, but they will serve maybe to round off the picture of crew psychology before we turn to more positive matters. One is the "clean" death. One of the ironies of the battlefield is that casualties who look half torn to pieces survive while the injuries to a corpse often have to be searched for. Sometimes a single fragment from a marginal penetration may kill a man inside a vehicle. Sometimes a man may be caught

by fire when dismounted. But by far the commonest victim of a bullet or splinter always was the vehicle commander with his head out (6).

This is why, as we shall see in the next chapter, good buttoned-up vision (or the equivalent) is so desperately important an element in fightability. It is also why duplication of facilities is of such value. In the four-man tanks of WWII loss of the commander put the tank out of action and often led to a serious sagging of crew morale. Israeli Centurion crews simply threw out the commander's body and soldiered on, with the gunner using the override controls to fight the tank from the commander's station. Their morale was seemingly unaffected. This is evidently the best course if the intensity of operations requires it. Otherwise experience and many grassroots accounts of armored warfare seem to agree that it is best for the crew to bury the body on the spot and carry on until a replacement can be brought forward.

The second case will I think - and hope - be rare in the future, because attacks which defeat the armor (and some which do not) will tend to be overwhelming in their general effect. It is when a vehicle is penetrated and a crewman takes the full brunt of the attack, leaving the other crewmen uninjured and the vehicle without widespread damage. The victim is likely to be ripped open, maybe disemboweled and/or dismembered. To put things bluntly, there is a bloody mess and it is very hard to get the body or its pieces out without making the mess worse.

With duplicate controls one can envision crews fighting on under these circumstances. The problem comes when they break contact. Experience once more suggests that this is not the job for the crew and their buddies. In the British Army at least the best procedure was found to be to get the surviving crew away from the vehicle, if possible putting them straight in separately as replacements for other crew casualties. The vehicle was then taken over by the technical section ("fitters") who drove it away, extricated the remains and cleaned and patched it up. I believe this would be essential even if the vehicle was fit to be fought on the remaining crew stations. But I find it hard to envision a modern vehicle being fit or locally repairable after a crew member had suffered devastating injuries of this kind.

On the positive side, the lesson is a very familiar one. Purposeful activity, preferably of a skilled, exacting and exciting kind, is the best antidote to fear and revulsion. In the future as in the past, armored vehicle crews are going to become extremely frightened and to face situations where they can scarcely contain their fear. This is yet another reason for the designer to aim at crew stations which provide optimum job satisfaction.

Notes

1 For certainty one needs hatches on **three aspects** or on **two aspects** and at **two levels** on one of them (as in a turreted tank with top hatches, driver's hatch and belly hatch.)

2 On one forties tank, I think either Comet or early Centurion, the commander could no longer reach the driver with his foot; but many tank commanders used pieces of string tied to the driver's arms like reins.

3 As distinct, of course, from outstanding tactical commanders and leaders of men who share and appreciate these feelings but can override them with their men's support when needs be.

4 I should say to readers that I have Centurion specifically in mind because I have practiced these drills on it in trials and training. But many tanks are similar in layout and present the same problems.

5 At least one WWII tank (I have to admit I cannot recall which but it must have been one with an epicyclic preselector gearbox) had a very crude device accessible to the commander or the loader, depending on the position of the turret.

6 Under some tactical conditions these losses can be crippling. The battalion I was serving in, 4th Royal Tank Regiment, lost over thirty tank and higher commanders in one day during the breakout from Tobruk (November 1941), as did one Israeli tank battalion in the initial breakout battle of the Six Days War.

CHAPTER 17

The Driver and His Station(1)

Up to this point this book has postulated a vehicle configuration and a layout for the crew compartment, and has progressively built up a microenvironment for the crew. We now need to review the distribution of the crew's duties and to flesh out their stations in terms of their combat functions.

First, though, it may be worth recapitulating the layout (fig 1, page 20). We have a crew of three located in line in a compartment sealed off from the frontal engine compartment and compound armor systems. The unitized electrical and electronic packs are positioned in the crew compartment around and to the rear of the crew stations. One or more access doors in the rear bulkhead of the crew compartment provide appropriate access to the magazine or functional module of weapon platforms and to the rear compartment of IFVs, CSVs and CSV variants. The driver is seated on the left in a nonrotating seat; for reversing he is presented with a rearward view by CCTV. The other two crew members are seated in a rotating control console or in separate identical stations, in either case with certain facilities including driving override available only in the 12 o'clock position. Slaved to their stations is the hull of a fixed gun TD or the weapon mounting of the FST, IFV, CSV and other weapon platforms (e.g. air defense). We noted too that it was not technologically necessary to rotate the commander and deputy commander, but was probably desirable from the psychological viewpoint in the first generation of vehicles to exploit the slaving principle.

This whole concept - indeed most future trends in the development of armored vehicles and antiarmor weapon systems - turn on two key assumptions about progress in the optronic field during the eighties. One is that a multisensor optronic system with a vidicon head as its principal element will at least equal first-rate optical systems for surveillance and target acquisition in terms of both physical performance and psychological acceptability. The second is that a practical short-range system of this kind can provide true binocular (that is, stereoscopic) vision for the driver. On the first, there looks to be general agreement among experts that, although the current state of the art does not meet these criteria, it would allow the establishment of a tightly-scheduled goal-oriented development program with a high chance of success and spinoff in every field from aerospace to consumer durables.

A predictable plus lies in the microprocessor control of the system. Image processing offers more than the combination of inputs from the various sensors in a form optimized for the human eye. It would allow each crew member to

select the magnification and quality of image (say in terms of contrast) best suited to his purpose at the time. Acquisition and laying, for instance, have different requirements; acquisition, like driving, calls for naturalness and optimum detail, while laying needs a highly contrasty image with a center of mass readily perceptible to the human eye. Additionally this approach opens the way to the integration of an automatic target acquisition system when one becomes available. The question mark hangs over reduction to manageable bulk of some elements of a system operating on frequencies and bandwidths selected for optimum resolution. The driving problem is a physical one at the man/machine interface and is discussed below.

The first question to ask is whether a crew of three is necessary. I am personally skeptical about this. One must however concede the Swedish arguments that the third man may be a tactical commander and that all major armored vehicles must be capable of carrying a tactical commander. In IFVs the third man will be the maneuver squad commander. In the FST (external gun with top traverse) there is probably a justification for rotating two men to divide surveillance between them (or to spell each other) as long as surveillance requires constant monitoring by the human operator. If the crew compartment of the whole vehicle family is to be standardized, the driver's station of a fixed gun TD will not be equipped for surveillance, so this task will again require two other men. Thus the design aim becomes in fact not "a one-man tank with a crew of three" (S tank) but "a **two**-man tank with a crew of three." This means **that the commander and deputy commander must have duplicate facilities with switching to give the override priority to either.**

Evidently any vehicle capable of firing on the move requires a crewman whose primary function is driving, leaving the commander and his deputy free to concentrate on planning ahead and bringing fire to bear. This remains true even if, at a later stage, these men cease to be physically rotated relative to the hull. In view of the attractions of the Swedish articulated concept it is worth noting that control of the rear unit in the vertical plane adds considerably to the complexity of the driver's task. Even if normal "contouring" is free or computer-controlled, the driver will require a separate lever for raising and lowering the rear unit when crossing obstacles or taking up a position. Likewise he will need **two** CCTV systems with separate monitors (because they may be needed simultaneously). One must show him the rear unit and the ground immediately around it; the other, for reversing, the view from the tail of the rear unit.

In a rigid vehicle he will need a single aircraft-type control column (joystick) with a thumbswitch for reverse. Either his reversing vision system must present a display with left-right inversion, or the reversing switch must invert the steering control signals. He can then reverse just as easily as he drives forward, except that he needs an additional control for adjusting the vidicon head. For reasons not connected with this argument, future high-performance armored vehicles are likely to need a two-range (road and cross-country) transmission. It would seem logical to incorporate the forward/reverse shift into this "transfer box" too and to provide full performance in either direction. The only other controls the driver needs are an emergency traverse switch to bring the console or center station to the 12 or 9 o'clock position (so that he can deal with a casualty or escape through that station); his headset switch, identical with those of the other stations; and a means of starting and stopping the engine. He will also have a battery of function switches and test buttons, but of these more in a moment.

With the high road speeds and usable cross-country speeds of the future, the

characteristics of the primary and override driving controls merit considerable thought. Unmodified velocity control (2) will evidently not do; nor will a step-phased system like that of a traverse controller (slew, lay, fine lay). Many systems of this kind use a mixture of velocity and position control (3). But since tactile (haptic) feedback **through the control column** (as opposed to tactile feedback through the seat and direct or indirect visual feedback) is always very limited in tracked vehicles, some kind of processing unit is going to be necessary. This unit must receive feedback on all parameters; there is as yet insufficient published data on the desirability of synthetic feedback to the driver's control in high speed tracked vehicles. More important, though, if this processor has to be there anyway, it could well accept additional inputs from position and rate gyros, thus providing what the Germans call "phase 1 stabilization." Quite apart from its effects on firing on the move, this partial stabilization of the hull might well ease some of the problems of suspension amplitudes and track dynamics associated with high cross-country speeds.

Certainly the driver will need excellent buttoned-up vision. The direct optical system needs a continuous horizontal field of at least 150° and a vertical field taking in the corners of the vehicle, this with binocular (stereoscopic) vision free of parallax. It should be possible to extend the field to either side by head movement. A system of this kind has three limitations though. There is a significant blind zone in front of the vehicle; it cannot be used at night; and the driver must learn to drive forwards on this system and backwards on an electronic display. He needs to be able to maintain high speeds on roads and cross country at night; and (as mentioned above) to have full performance available in reverse.

Maybe then the optical system should be a fallback and we should look for a system which will present the driver with a consistent display forwards and rearwards by day and by night. This is doubly attractive since the same display will be required in other stations for relief driving by night. All this calls for an indirect (optronic) system. By the nineties there should be little problem about providing cameras capable of operating at all light levels, maybe with rather better penetration of mist than an optical system. But now comes the rub. To drive at the kind of speeds envisioned, above all to read ground, the driver needs true **bino**cular (stereoscopic) vision. The **bio**cular (simultaneous) vision (4) provided by a video monitor is not adequate, because it gives only limited perception of depth (in the sense of judging distance).

On the rationale of relative costs I have followed in this book, it has to be acceptable to twin the camera units, the more so since this provides the redundancy needed for a biocular emergency system. Likewise there would be no difficulty in setting up twin units to provide a base length similar to the human interocular distance with the minimal convergence typical of driving distances. (Theoretically it would be feasible to monitor the driver's eyeball movements and slave the cameras to these; but this seems superfluous.) Biocular on a fixed field is almost certainly adequate for the conditions when the commander or deputy commander overrides the driver for tactical maneuver or spells him on long moves. So there remains just one problem - **how to get the two images to the driver's eyes in a way that is physically, physiologically and psychologically acceptable!**

We can narrow the problem down a little further by accepting that all subsystem warning lights would be duplicated by an audio warning (as they must be for the benefit of another crewman spelling the driver) and that positive readings can be called up and superimposed on the display (again as they have to be for other purposes). It would likewise be feasible to have the

audio warning trigger a visual display of the problem reading or even a simple verbal audio input like "overheating", "oil pressure low" or "no charge". So the driver only needs to look at his display, not to turn his head or eyes and accommodate to other visual inputs. We can give him the next thing to eyeballs on stalks by adding to the forward/rearward vision selector switch a joystick which traverses and elevates the twin camera heads. We can miniaturize the driving control column and bring this to one hand and the camera joystick to the other. We can then secure the driver firmly in his seat, restraining his head and his arms between elbow and wrist.

In saying this I am deliberately ruling out the use of goggles or some form of viewer attached to the helmet. Keeping the eyes focused at something less than normal reading distance is injurious and tiring; and an optical system to overcome this problem introduces a further artifact. It is questionable whether the brain would accept signals so presented; certainly experience with night driving aids of this kind was very negative. More questionable still is whether the additional claustrophobic effect would by psychologically tolerable in an armored vehicle environment. One might say the same of head and arm restraints in addition to a body harness, but this need not be so if the restraints on helmet and forearms are of an "inertia" type which matches the harness in firmness of action, and from which the man can release himself simply by a sharp movement.

Once the driver's head can be brought to a given position and angle relative to the hull by a sufficient number and range of seat adjustments and kept there, the pair of monitors can be fixed relative to the hull. Adjustment of them for the individual's interocular distance would probably be necessary but would present no difficulty. Once the distance from the eyes and the size of the displays had been optimized, trials would be needed to establish whether a separating screen was necessary, and if so how far towards the eyes it need protrude and what maximum thickness could be tolerated. A screen of this nature (or hoods on the monitors) would evidently be a hazard both if the driver was thrown forward by a violent rearward acceleration and when he was moving around in his station.

At the time of writing, the difficulty of driving an articulated vehicle with "vertical steering" when buttoned up has yet to be assessed. For a rigid vehicle the driver can probably be a rather lower standard of man than the commander and his deputy; more important, though, he needs to be a rather **different** kind of man, somewhat in the direction of the traditional "driver/mechanic." Temperamentally, like the driver of a conventional tank, he will tend to be the steadying, down-to-earth influence which offsets any prima donna-like tendencies in other crewmen or tactical commanders. Because he does not have a surveillance task, he will also tend to become the handyman of the crew. I used the term "driver/mechanic"; in fact his technical training needs to lean towards the electronic side, albeit at a very elementary level. He is the guy who actually does the crew repairs we discussed in Chapter 11.

Above all he will need to be a very good driver. Even Abrams, with much lower road and cross-country speeds than the lighter high-performance vehicles of the nineties, is producing problems in driver training, above all in drivers' ability to read ground. So one need not suppose that this future driver's training will be simple, quick or cheap. The traditional manual skills of driving may have been virtually eliminated, just as they are in many current armored vehicles. With an optronic primary vision system, much training and practice can be done on a simulator, or on the vehicle itself with the aid of video and audio tape inputs. Teaching a driver to read ground is

another thing again; I believe it calls for an indirect approach.

In the type of composite unit I have consistently envisioned (5), crewmen would start with a stint in the maneuver squad. There they would learn fieldcraft. The most intimate appreciation of ground at speed comes from cross-country motorcycle riding. This is a very cheap training expedient, and a highly attractive one into the bargain - not to mention its value in building character. The next transition could be from that to "special section" rally driving, paralleled with acclimatization on a simulator to buttoned-up driving by binocular CCTV. The simulator program could be made progressively more advanced to a point where it married up with rally driving in terms of appreciation of ground. Then training on the armored vehicle itself could begin.

It will have struck the reader that discussion of the use of optronics as a primary vision system for driving opens up not just a nest of problems but a number of highly interesting, not to say rather dramatic possibilities too. I should prefer, though, to leave exploration of these over until the end of the next chapter.

Notes

1 Because this chapter draws on numerous inputs from earlier in the book, I have limited cross-references to key points so as to avoid interrupting the flow.

2 In which the strength of the control signal is proportional to the deflection of the controller.

3 In position control the position of the controller signals the required position or heading of the object controlled.

4 In **bio**cular vision the **same** image is seen by both eyes and perception of depth is based only on interpretation, not on stereoscopic effect.

5 In my previous military books and a number of articles.

CHAPTER 18

The Fighting Crew and Their Stations

To recapitulate once more, the right-hand part of the crew compartment consists either of a two-man control console with 360° traverse or of two separate duplicate stations. When the vehicle is not being fought, these stations are locked in the 12 o'clock position. Here certain additional facilities, mainly concerned with crew comfort, are available. Either crew member can maneuver the vehicle from any position of the console or cupola, or of his multisensor head, in which he can see to do so; but he will have true binocular vision only when using his direct optical system, and rear vision only to the extent provided by the multisensor head on the weapon mounting (or on a separate pillar in the case of a fixed gun TD).

There are three solid arguments for providing these men with duplicate facilities and interchangeable priority of override. With an antiarmor range of 4500 m, the area of real estate to be kept under surveillance is at least 30 km^2. To achieve reasonable security - in other words an acceptably high probability of an available target being acquired - and to keep acquisition times down to an acceptable mean value, the surveillance task must be divided between two men. Second, considerations of tactics and terrain call for the crew member who acquires a target to have the option of engaging it (which may involve maneuver) and allowing surveillance in the other man's sector to continue, or of handing it over and himself continuing surveillance. Third, having narrowed the scope of the driver's function as compared with that of the driver/gunner of S Tank, human factors and battleworthiness alike requires that the vehicle can be fought by either the commander or his deputy.

By contrast, once the primary vision and sighting system has become optronic rather than optical (page 122), most of the arguments for rotating these two men collapse. This provides a nice example of the distinction between cost-effectiveness and cost-benefit analyses. At the physical level the advantages of **not** rotating these men are substantial in terms of direct cost, far more so in terms of design characteristics offering improved capabilities at lower weight and cost. The sole concrete argument that remains is the need to be able to use an emergency optical system. Yet (as mentioned earlier) the psychological drawbacks are severe. Thanks to its number of cells and its synaptic links, man's central nervous system is wonderfully sophisticated in comparison with predictable, let alone existing, electronic systems. But there are some relatively elementary situations it cannot cope with, and one of these seems to be orienting itself with respect to three simultaneous axes in the same plane.

Experience with Conqueror (cf page 116), and even with contrarotating cupolas, leaves no doubt that the man's head at least must be physically aligned with the axis of primary interest (say target azimuth). He can then retain and update the angle between this and one other axis (say direction of travel) and subconsciously perform the necessary resolutions.

The Soviets and a substantial German school of thought apparently consider that the design pros of a rotating-head primary (optical) vision device outweigh the cons. So they would logically go for its optronic equivalent, leaving the commander's head and body fixed in relation to the turret (or hull as the case may be). By contrast American, British, Israeli and Swedish designers **and** users seem to be unanimous in the conviction that waist-upward turning of the body is essential for orientation (1).

With an all-around optical system and the normal human suppleness and field of vision, this arrangement gives a seated man azimuth fields of almost 270° for unity power vision, some 180° for surveillance with magnification, and around 150° for comfortable line-up of the head. The extent to which the hips can normally be twisted even in a contoured ("rally-type") seat adds maybe 30° to these arcs; and since I can still achieve them as a fat old man, youth and physical education could well extend them still further.

In a turreted tank, though, I have to admit that I was never able to maintain orientation with respect to turret **and** hull when using a rotating cupola. With a contrarotating one, my orientation used to collapse completely in the period between initiating contrarotation and achieving line-up (2); and I could never regain orientation with respect to the hull until I had passed the target to the gunner and could snatch a quick glance through the unity power periscope ring. My subjective impression, based on extensive discussions in the contexts of policy, trials and training, is that only a handful of tank commanders were exempt from this confusion. These tended to be the experienced and highly talented noncoms, most of them gunnery instructors at some stage, who moved on through commanding user trials vehicles to commissioning (at least in the British Army) and to key positions in the training organization. I am inclined to think that the ability to retain orientation is one distinguishing mark of the truly professional tank commander.

This suspicion of mine was strongly reinforced by monitoring battle runs and marking tank platoon tactical tests. It seemed reasonably evident to a seasoned and skeptical eye that eighty per cent or more of field force unit tank commanders were apt not to have too much idea where they were going, or looking, or shooting. This was one factor that led me to press very strongly - and in the end successfully - for British troop trials of S tank on top of the normal "exchange" user trials (3). For in a fixed-gun tank the lower half of the commander's body can remain aligned on the **hull** axis, so that he gets a continuous tactile input of this. By the same token, a commander seated in this manner in the hull of a vehicle with a slaved weapon pod does not have to worry where the gun is (4). This "semifixed" position of commander and deputy commander or gunner is in fact the first choice of the Swedish user for that country's next generation of AFVs. Complete rotation (seemingly favored by the United States) comes second, and a fixed position with a rotating head sight (or rotating multisensor head) a very bad third.

Fact is I opted for the two-man rotating console in *Antitank*, and thus as a point of departure for this book, because this was the only way I could see of putting a three-man crew in line with 360° direction vision while keeping a fixed gun at least approximately central - something I felt to be essential for automatic loading of two or more types of round. Recent thinking on magazine arrangement and autoloader design for fixed guns removes this constraint; and

there is of course no design reason why a fixed gun cannot be moved right over to one side as long as its bore axis (and hence its trunnion reaction) is truly parallel to the hull axis. A weapon mounting with low recoil forces can be staggered longitudinally and laterally to a position behind the driver (as

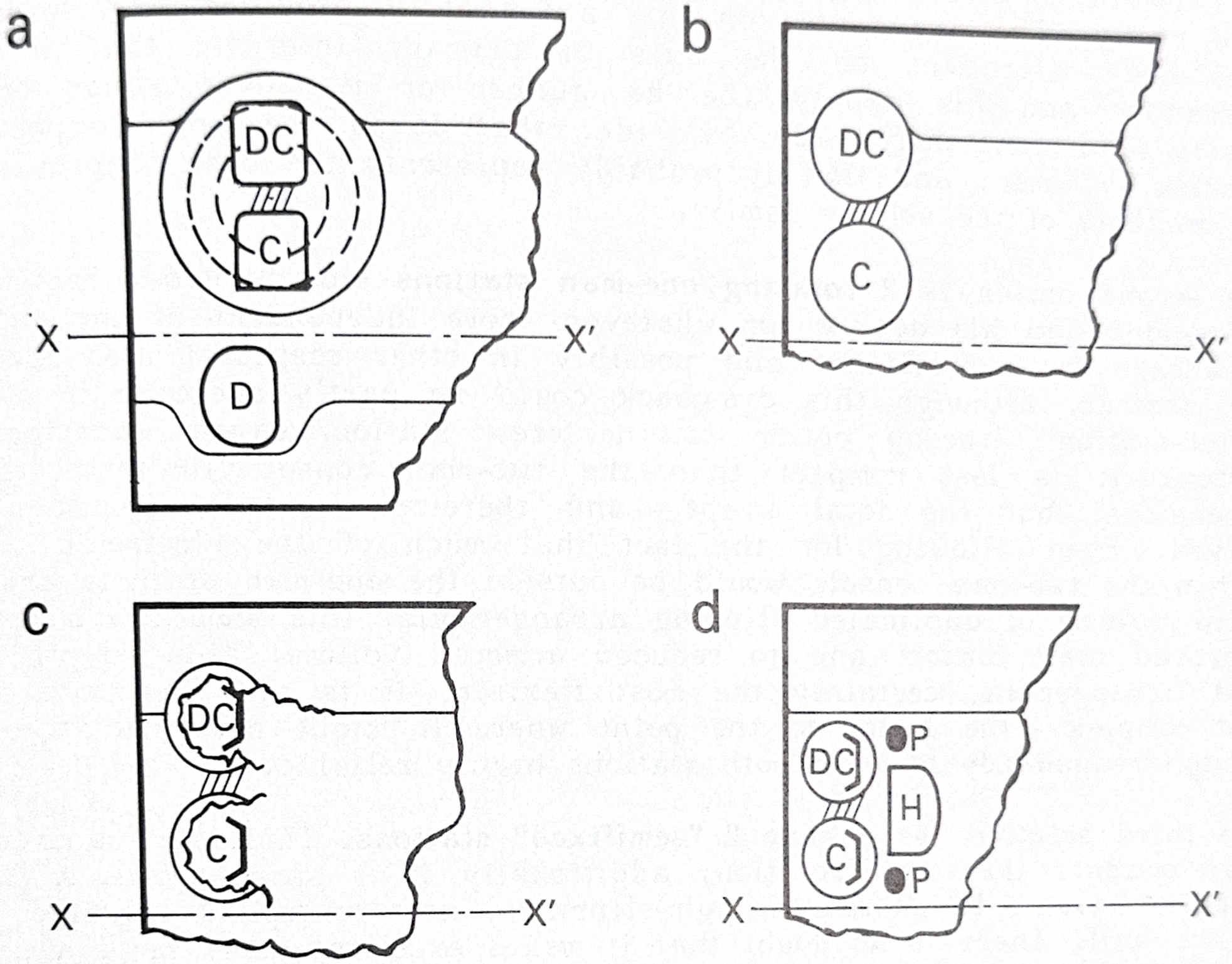


Figure 15. Crew station layout options

▨ = zone of mutual interference, C = commander, D = driver, DC = deputy commander, H = hatch, P = pillar of dome lid, XX' = right hand edge of clear fore-and-aft space for gun tube (fixed gun TD), forward bridge support (AVLB) etc.

a. **Two-man control console.** The outer **(full)** circle represents diameter above roof level, the middle **(dotted)** circle down to track level, and the inner **(broken)** circle at floor level. The two men do **not** rotate separately relative to the console; they have conventional hatch-lids immediately over their seats.

b. **Separate rotating stations** with conventional hatch lids above.

c. **Separate "semifixed" stations.** Here the seat is fixed, but twisting of the upper body gives a 270° arc. Since the part of this arc on which mutual interference occurs is wasted, it would theoretically be possible to obtain rear vision by offsetting each station 45° "outwards." But the resulting orientation problems are almost certainly unacceptable. Hatches are again over seats.

d. (cf fig 16 and related text). Here the fixed stations are each covered by a semipermanent transparent dome, with a large common hatch to the rear (acceptable since with fixed stations any crew member also has access to the driver's hatch and **vice versa**). The domes have lift-and-turn armored lids (sheaths).

in my IFV/CSV solution, on which figure 1 is based); and a traversing mounting for a high pressure gun can, and indeed for many reasons must be on the hull center line behind the crew compartment. In these terms one can put three men in line and have four options for the design concept of the fighting crew's stations.

One remains the **rotating two-man console,** which can now be made slightly more roomy. The arguments for this are that it provides 360° coverage with whole-body alignment on the axis of primary interest; that it puts the commander and his deputy (be he gunner or maneuver squad commander) closely and constantly side by side; that it is the most compact way of rotating two men; and that it probably represents the best compromise for all key members of the vehicle family.

The second option is **2 rotating one-man stations** side by side. This makes the commander and his deputy (or whatever) more independent of one another, an advantage for surveillance and possibly in other respects; also remoter from one another, although this drawback could be partly overcome by adding an "inter-station" line-up option to the crew station/weapon mounting line-up system. It is less compact than the two-man console in terms of overall dimensions, but the total swept - and therefore wasted - volume is almost halved. Even allowing for the fact that much of the electronics contained within the two-man console would be outside the one-man stations and for the extra volume of duplicated slipring arrangements, this should add up both to improved crew comfort and to reduced armored volume. This is probably the best arrangement, certainly the most flexible; it is also the most expensive and complex - the latter to the point where it might be difficult to provide enough redundancy to make both stations highly reliable.

The third solution is to have **2 "semifixed" stations.** This is much cheaper and more compact than full rotation; additionally it is simpler because far fewer circuits have to be passed through sliprings, most controls being fixed relative to the hull. There is no doubt that it makes excellent sense for a vehicle with a fixed gun or limited usable traverse and an **optical** primary vision and sighting system. The great drawback is rear vision; rear driving by any crew member becomes dependent either on optronics (admittedly with 100 % redundancy from the driver's and vision/sighting systems) or on one crew member kneeling in his seat using an emergency periscope and emergency controls. However this may be the least of the objections to so stringent a limitation on rear vision. Because to do so is awkward optically and confusing electronically, nobody is going to cover the rear much; the vehicle will have an almost permanent and infinite blind zone over its 90° rear arc. This is completely unacceptable for IFVs with their maneuver squads dismounted; it carries a high tactical risk for weapon platforms too.

Once one goes optronic, though, "semifixed" stations are no more than a psychologically necessary halfway house on the way to fixed ones. As my remarks above will have indicated, I am deeply conscious of the orientation problem; this is in fact a physical, or at least a neurophysiological one, just as real as if it lay in a nut and bolt or a computer circuit - and much more important. I am less sure, though, that the use of upper-body rotation offers the cheapest or most effective short-term palliative, let alone a real solution. Suppose we just stand off and take a look at the optronic inputs we have so far stipulated. We have a **bino**cular (stereoscopic) system for the driver, from which a **bio**cular (simultaneous, nonstereoscopic) signal is fed to the vision/sighting system for driver relief on long moves. This system is looking roughly along the vehicle axis, normally forward or, when required, rearward. Sure, its camera heads and therefore the center line of its field can be varied by the driver in both planes; but once one has taken out a single-channel

(biocular) signal of the whole field, it is no great problem to lead this in two directions - as a full-field full-screen display for relief driving, and in some other way as an aid to orientation.

Following this second part, one can envision a relatively simple device (either making use of the weapon stabilizer inputs or generating its own) which would take, at a guestimate, three quarters of the driver's horizontal field and one half of the vertical and would center this reduced field horizontally and vertically on the hull axis. Given the image processor already discussed (page 122), it would be easier still to put this reduced, stabilized image onto the bottom part of a square display at the fighting crew stations, below a "landscape golden square" (1.6 wide x 1 high) vision/sighting display and with the centers of the two fields at the correct relative azimuths. As the vision/sighting multisensor head was traversed to and beyond the horizontal limits of the "hull" field, the amount of "hull" field visible would progressively diminish until, at 3 o'clock and 9 o'clock, only an indicator line was showing at the appropriate edge of the screen. Since a signal will be coming in from both front and rear driving cameras all the time, there is no reason why both inputs should not be crossfed, and the rearward input taken up when the multisensor head was turned to the rear of the lateral hull axis.

Let me be the first to say that I am speculating wildly and that a display of this kind might prove to be very expensive and utterly confusing. No matter. The point I want to make is that electronic solutions to the orientation problem probably exist and are certainly worth exploring.

Nonetheless one can expect the abandonment of high-grade optical vision systems to encouter massive user resistance; and this may well be justified in some measure. As I stressed earlier, the crux of the matter is target acquisition, most of all detection. Even when optronic systems have achieved the technical goals set, there may still be conditions - large-particle dust on a bright, clear day for instance - where an optical system will do this job better. There are two snags about use of a retracting periscope as an adjunct to the layout discussed above. One is that, except with a fixed gun configuration, any vertical protrusion which does not traverse concentrically with the gun will be fouled by the gun tube. (The briefest of glances shows that any system of retraction and interlock would be too slow and would deprive the commander of vision at the moment he most needed it.) Second, to put the image where the commander and/or his deputy can use it without great optical complexity and loss of quality means retracting a long, large-bore tube either between a crew member's legs or between two crew members, thus wrecking freedom of movement and habitability.

This is why, in their articulated antitank gun, the Swedes propose to surround the commander's station with a cylindrical sheath and elevate the complete station to gun-mounting level. This solution brings in its wake great complexity and sacrifices much protection; it may be marginally acceptable for the antiarmor role in a positional defense but is evidently (as even its protagonists admit) a nonstarter for mechanized operations. There is no problem about running an extended periscope, with or without a rotating head, up one or both sides of the gun trunnion supports. But if one man is put under the gun, as in the Marder/105 mm test rig (pl 2) and some American sketches (5), the surveillance task cannot be shared. So we come right back to rotating the fighting crew concentrically with the weapon pod in a kind of "flush-roofed turret" (not too unlike the M60A2 compact turret minus its rear cupola). This is why I emphasised earlier that the success of a multisensor optronic vision and sighting system was probably the most critical single factor in armored vehicle development astride the turn of the century.

We are still left, though, with a further unresolved psychological drawback to going optronic. Sure, almost seven decades of development have failed to produce a vision system with which commanders are prepared to fight buttoned-up; nonetheless offering the user a vehicle which encourages the commander not just to put his head out but to stand on top of his cupola would scarcely add up to a great leap forward. As I likewise already stressed in several contexts, the human brain seems unable to analyse sensory inputs to its own satisfaction unless it has enough data to reject some as redundant.

This characteristic seems to apply with particular force to the amount of visual information an armored vehicle commander needs if he is to feel in control of the situation. Even Israeli tank commanders cannot all be heroes with an urge for martyrdom; they evidently find the high risk of being shot in the head less frightening than a lack of **redundant** visual information (6). So we need to explore in some depth, in terms of both optical and optronic systems, ways of providing "natural" buttoned-up vision for the commander and his deputy - or for tactical and vehicle commanders.

As a point of departure we might take a long, hard look at the threat of ballistic attack on the commander's head and the part of the armored envelope

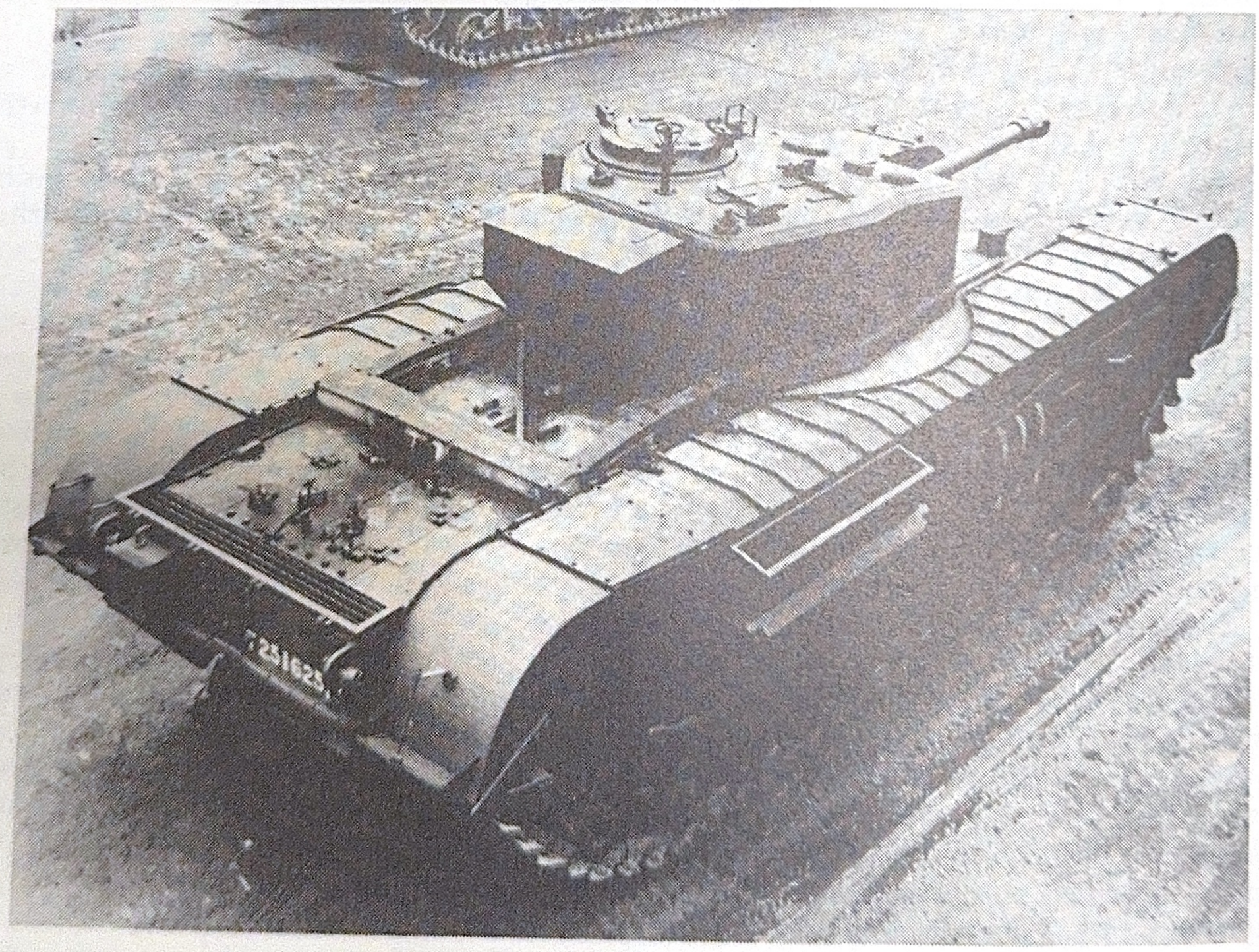


Plate 7. CHURCHILL VII cupola

This view of the British WWII Churchill VII "infantry tank" (ie heavy tank) shows a commander's cupola with an early design of "all-around" vision. In fact the field of vision was interrupted, parallax effects from head movement were extreme and there was no provision for magnified vision. This tank could not be fought effectively buttoned-up except for short periods in very simple situations. Note the "blade vane sight" on the turret roof, used by the commander when ordering the gunner to traverse onto the target.

surrounding it. One of the classical principles of British protection policy - and one that added significantly to the height above trunnions of British tanks - is that, in the buttoned-up position, the top of the commander's head must be below the level of the turret roof. The implication was that the cupola could be shot away over his head without his suffering serious injury.

There may have been some force in this argument in the days when commanders' stations just had a fixed ring of unity power periscopes in the turret roof and a tilting periscope also in the cupola lid (pl. 7); though even then it would have taken a remarkably clean strike to leave him intact. Once the vision system was built into the cupola ring (pl. 8) and the forward-looking instruments became rather massive, a fair strike on the cupola was evidently going to push the lower half of these instruments straight back into his face with considerable force. Just as evidently the cupola and the surrounding roof area would not save the commander in face of a direct hit on his station from a descending or downward-looking antiarmor weapon, or even a medium/heavy HE shell. At the other extreme a commander with his head out or even just his hatch unbuttoned is vulnerable to anything from a 5.6 mm pistol bullet or the smallest half-spent HE/HEP fragment upwards (7). In other words **the best level of protection one can hope to achieve over the cupola area is the same as the vehicle's all-around protection - that is against small arms and splinters; but this will enormously increase the commander's chances of survival if it is combined with good enough vision to keep him buttoned up.**

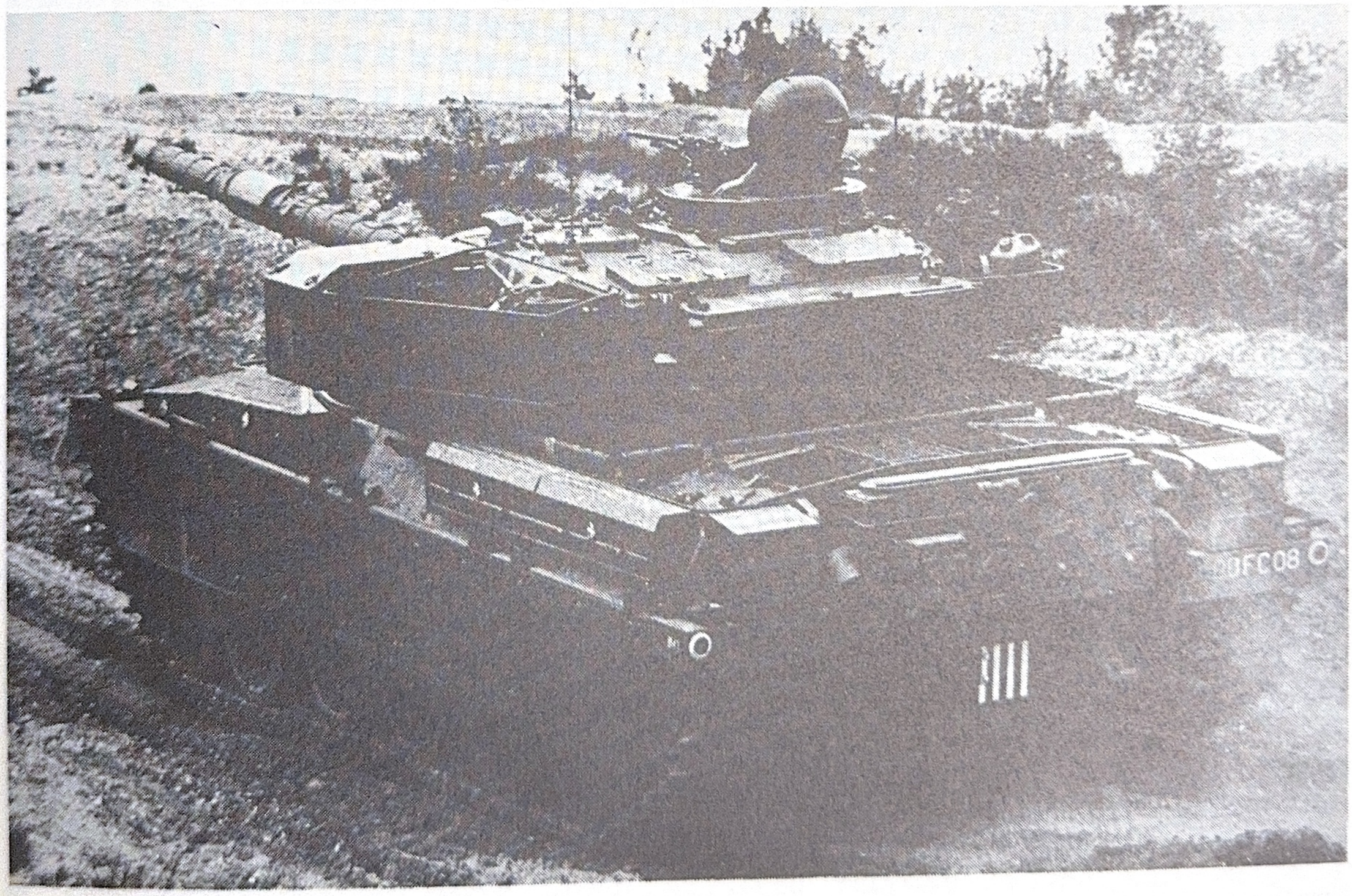


Plate 8. CHIEFTAIN cupola

The cupola on this British Chieftain typifies modern British thinking. In the buttoned-up position the commander's head is below the level of the turret roof. The x1 periscope ring is in shadow below the surface on which the commander's hand is resting. The casing of the primary binocular vision/sighting instrument can be seen above the commander's wrist watch, to the right of the machinegun mounting.

There is one other piece of conventional thinking we need to sweep away. The arguments for combining the commander's vision arrangements with his hatch are extremely strong. But if he has completely satisfactory buttoned-up vision they cease to be overwhelming. As long as enough other roof space can be found to give the commander and his deputy normal access plus two emergency escape routes (page 114), there is no need for the "cupola lid" to be opened easily - or indeed at all.

With a realistic idea of the attainable level of protection and no rigorous restriction on the weight or configuration of the cupola lid, we can take a look at the fields of nonmetallic materials technology - in this case armored glass or possibly a toughened transparent plastic. Starting with the profile of the vision blocks of modern American cupolas (pl 9), we can develop this into a continuous dome (fig 16). This gives the commander uninterrupted natural vision over a 360° horizontal and a 180° vertical arc. On available data a feasible dome of this kind would provide about the required level of protection to the commander, but strikes on it would almost certainly lead to weakening of it and loss of transparency. So two further needs arise.

Plate 9. M60A1

The view of the cupola of this M60A1 shows very clearly the difference between American and British thinking (cf pl 8). This is virtually the upper part of a subturret (cf Conqueror, pl 6). Note the x1 vision blocks (eg seen in line below the rearmost antenna) and the primary vision/sighting instrument. Part of the height and bulk of this cupola is due to the user requirement to have the machinegun mounted under armor.

One is for a lift-and-turn steel lid, operable from inside the vehicle, with two "closed" positions. One would leave a horizontal vision ring with a vertical field roughly equivalent to that of existing vision blocks; this would be used in conditions where the probability of a strike is high and most commanders would button up a conventional cupola - also to limit sun glint. The second position would provide full closure for blackout and elimination of sun glint. The other requirement is for the dome to be replaceable, preferably from within the vehicle. If this could be achieved - for instance by a downward cylindrical extension of the dome with an interrupted thread or a ring of rotatable retaining catches - the cupola would continue to provide an emergency exit.

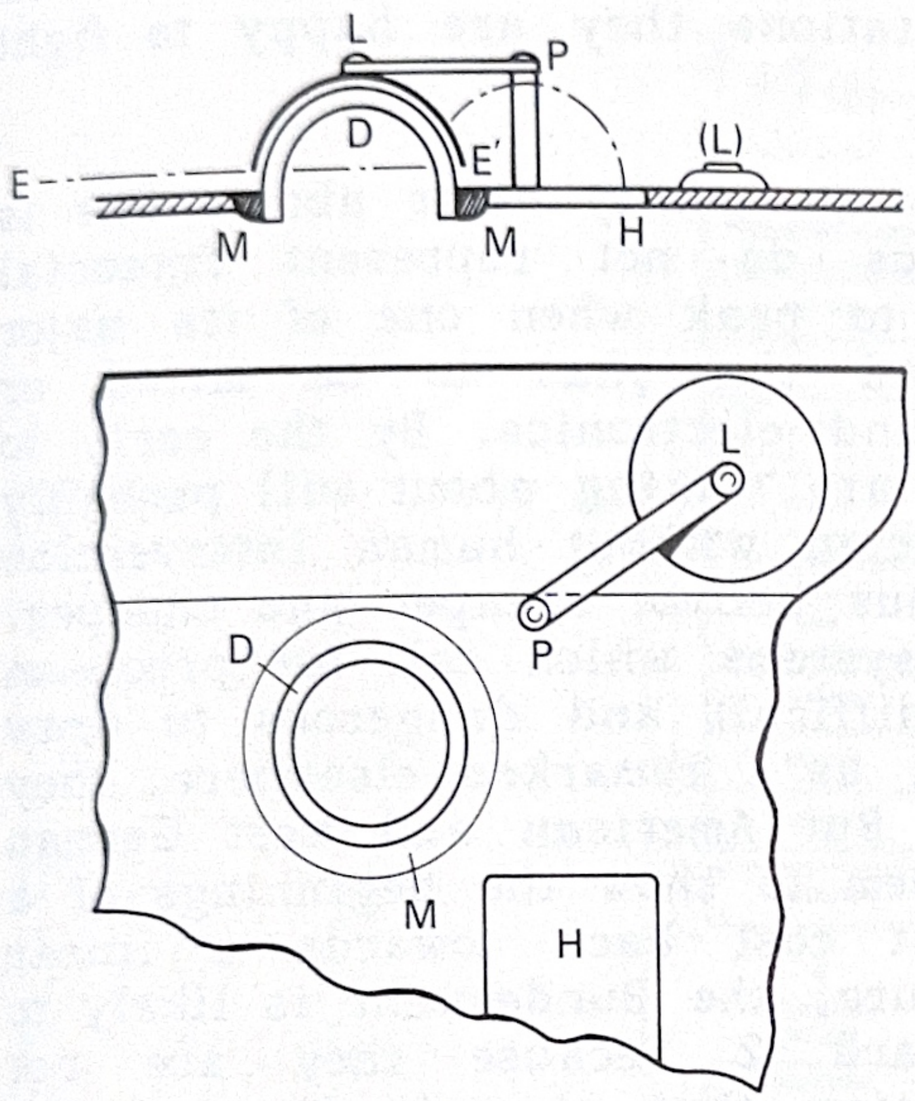


Figure 16. Cupola dome

D = dome, EE' = highest eye level, H = hatch (lid not shown), L = armor lid (lift-and-turn), M = dome mounting ring and fitting arrangements, P = lid pillar. This shows the right hand (deputy commander's) station. The transparent dome is semipermanent but replaceable from inside the vehicle. In the elevation the lift-and-turn lid is shown in its "slit vision position"; this provides vision equivalent to vision blocks (eg M60). When not required, the lid fits into a recess in the pod (sponson) over the track, as shown in plan, so that interference with vision is minimal (ie (L) shown dotted in the elevation).

Oddly enough, a dome like this marches much better with an optronic vision/sighting system than with an optical one. The heads of the primary instruments of an optical system are necessarily large; if the instruments incorporate dual magnification, a "direct" night vision aid and/or a laser range finder, they are larger still. And they come just where the commander using the natural vision of his dome least wants them. By contrast, going along with the "natural" approach, unspectacular but steady and long drawn-out progress in basic optical technology now offers compact hand binoculars with very acceptable combinations of magnification, field and light number at around the weight and size of opera glasses. Provided the internal dimensions and optical design of the dome were suitable, the commander could use binoculars like these within his dome.

By the nineties it may well be feasible to put a head-up display into the lower part of a dome of this kind, but I am not convinced that it is necessary or even desirable. The dome would be fixed relative to the hull or to a two-man console. In a fixed or "semifixed" station (see preceding section) the dome could have "clock" azimuth indicator marks at its lower edge; with an equivalent control, the commander could very easily call up the sector required onto a display below roof level. To make full use of the vision offered by the dome, though, I reckon the commander and the rest of his station should rotate underneath it. This argues for two separate stations (fig 15b, page 159) -

and for two separate multisensor heads, of which more in a moment. With that layout, a sensor head would be indexed to each rotating station, so that the commander or his deputy could look down and see on his monitor exactly the field he expected, presented in the surveillance mode.

Once again I confess to wild speculation in a number of directions, and I am more than ready to be taken to task where I am wrong. I am trying to build up for the reader a picture combining realistic requirements and feasible solutions into a pair of commander/gunner's stations which - after years of feeling woefully inadequate as a tank commander - I reckon even I might be able to fight. Without hardware and trials, though, one cannot judge the across-the-board outcome of various approaches and technical solutions. One thing I am quite clear about is that the commander and his deputy (as I am sure he must be called) have to be given stations they are happy to fight buttoned-up.

There are two further aspects of this trend I am equally clear about. One is that ventures into optronics and electronics do not represent financial extravagance. The cost of a system is apt to peak when one of its major subsystems is in a state of transition and thus has to be mixed or duplicated - in this instance between optics and electronics. By the early to mid nineties the level of electronic system we are talking about will probably be not just produced but designed and inspected without human intervention beyond feeding in the requirements. It will thus become cheaper and cheaper, while the cost of optical and mechanical subsystems which call for precision forming and machining will escalate. It is difficult and dangerous to draw even broad conclusions from published figures; as I remarked elsewhere, they are apt to have one key parameter missing. But American and West German figures even for seventies armored vehicles seem to show the beginnings of a move away from an electronic-dominated unit cost back towards a linear relationship between cost and battle weight. Sure, the Bundeswehr is likely to abandon some of the electronics of Leopard 2 because they are not cost-effective. But one also has the impression that this is because the elements in question are superfluous, ineffective or unreliable rather than on grounds of absolute cost (8).

The other aspect is the tendency among analysts and designers who lack real or vicarious experience of tanking to regard a switch from optics to optronics as the point of departure for the removal of the crew from the upper front of the vehicle (or articulated train) initially to the rear of the vehicle/train and later out of it and into a kind of command vehicle operating, say, a platoon's worth of robot tanks by remote control. With a high risk of overhead and over-the-crest attack, grouping crews in one vehicle is a folly many orders greater than fielding command vehicles (in the normal sense) with a distinctive visual signature.

If the crew is in the rear of the vehicle, they cannot operate it in emergency by means of a secondary optical system or unbuttoned. The technical arguments for putting them there are irreproachable - indeed irresistible. But these arguments contravene the principle of keeping the man in the primary control loop. If "the moral is to the physical as three to one" - and few with experience of combat question this - combat effectiveness lies in keeping the man where he can pull something out of the bag, if needs be with his naked eye and bare hands. In this book, as elsewhere, I have urged the extension of the soldier's senses and the reinforcement of his muscles with every relevant device. But I hope I have also driven home the need to leave him right in there pitching.

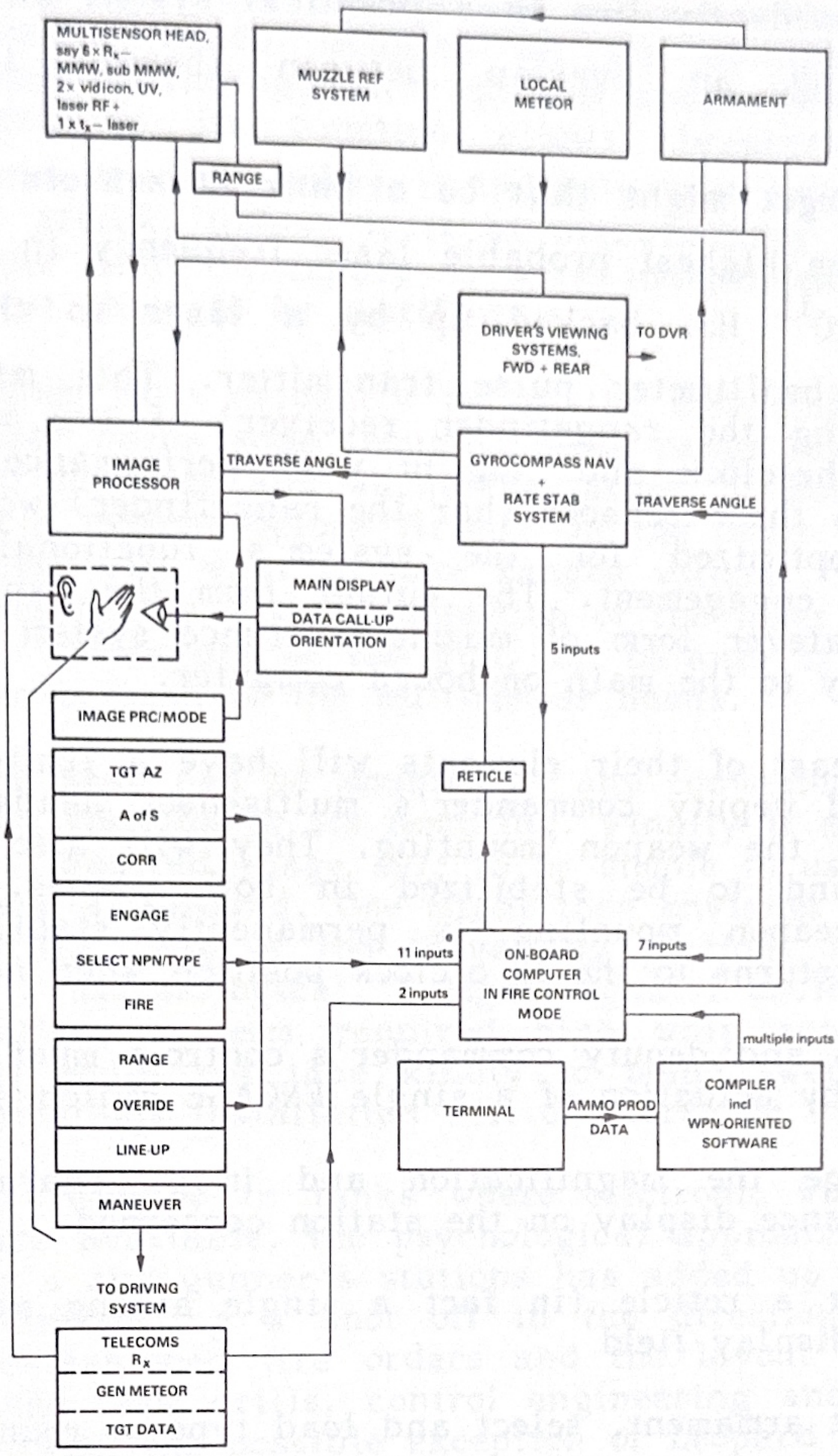


Figure 17. Fire control/gun control schematic

This block schematic attempts to show the complete vision, sighting and control systems bar the driver's display and control systems, which are indicated with a label and a scrap line. Also omitted are - the linkups of the on-board computer in its other roles (eg troubleshooting); the inputs for training and entertainment (Chapter 4); and a number of other secondary functions.

Like many others, I find it all too easy to fall into the trap of talking about **multisensor heads** without going too closely into what is involved. My earlier examination of armored vehicle signatures (9) still leaves me convinced that the system must be based on the visible spectrum and its fringes. Sensors are as vulnerable to whims of fashion as the length of skirts and even more sensitive to the "countermeasures to the nth" game. At the moment our natural visual perception is extended by photoelectric and thermoelectric means from visible frequencies (around $8\text{-}4 \times 10^{14}$ Hz) downwards by a couple of orders of magnitude to far infrared (unit teraherz or 10^{12} Hz). Electronics provides us with another window now running upwards in frequency from unit gigaherz (10^{9} Hz) to around 10^{11} Hz (millimeter waves, MMW). Electrically produced signals verging on the order of 10^{13} Hz have long been feasible in the laboratory. So

future interest evidently lies in a practical system which would join these two windows, offering an overlap between thermal imaging and radarlike techniques.

A reasonable target might thus be a bank of sensors providing uninterrupted cover between the highest probable laser frequency in the ultraviolet (10^{15} or 10^{14} Hz) and 10^{11} Hz, backed up by a laser in the visible band and a millimeter or submillimeter pulse transmitter. This might require up to six sensors (including the rangefinder receiver) if two vidicons were needed to optimize round-the-clock and "fog of war" performance. As discussed earlier, the outputs from these sensors (bar the rangefinder) would be processed into a single image optimized for the system's functional modes - surveillance, acquisition and engagement. The output from the rangefinder, meteorological sensors and whatever form of muzzle reference system was incorporated would be fed separately to the main on-board computer.

Since some at least of their elements will have a limited horizontal field, the commander's and deputy commander's multisensor heads need to be traversed independently of the weapon mounting. They will also be required to elevate and depress, and to be stabilized in both planes. As with conventional systems, the weapon mounting is permanently stabilized in elevation but remains at, or returns to the 12 o'clock position when not in use.

The commander's and deputy commander's controls must be extremely simple; I see no reason why actuation of a single ENGAGE switch should not -

change the magnification and image characteristics of the surveillance display on the station concerned

inject a reticle (in fact a single aiming mark) into the center of the display field

select armament, select and load type of round

line up the weapon mounting via the on-board computer (in its fire control mode)

present a GUN READY indication in the display

activate the firing circuit

A FIRE button initiates the range taking and firing sequence, this sequence being interrupted by release of the button should the target disappear, a friendly element converge on the line of sight, or whatever. The other station would remain throughout in the surveillance mode - or initiate the ENGAGE sequence on a second target. Once its ENGAGE switch was set, the engaging station would retain control of the gun until the switch was reset to SURVEILLANCE unless the commander operated a gun control override (10).

We will pursue the question of controls further in a moment; but we are now in a position to examine the physical characteristics of the multisensor heads. Because these protrude well above the hull roof, the units as a whole must traverse concentrically with the gun, even if the composite head is stabilized independently of it. It may be worth recapitulating at this point that all stabilizing signals are generated by a common gyro unit in the hull and resolved and applied to various subsystems as required; nonetheless an additional input is needed to allow for displacement of the heads relative to the hull when the gun is traversed. The heads cannot be mounted on the

elevating mass, since they must not elevate and depress with the gun. I see the surveillance multisensor heads mounted on top of the gun trunnion supports, with their elements arranged for optimum compactness and the head housing as well armored as its function allows. Separation, along with shielding by the gun and cradle, makes it unlikely that both heads will be knocked out by any one attack, unless it is at overwhelming level. Since two heads allow the commander and his deputy to work independently **and** provide 100 % redundancy, the cost looks to be justified.

The muzzle reference system must evidently be on the elevating mass, but the location of the rangefinder needs some thought. Since range taking renders the ranging vehicle liable to detection and warns the target, it must normally take place at the last possible moment before firing. On the other hand there will be occasions when a crew will want to take ranges without firing; they will certainly not wish to add to the risk of detection of the laser flash and much greater one of giveaway movements of the gun. On balance it seems sound to incorporate a rangefinder in each of the multisensor heads.

The meteorological sensor head can be mounted at any convenient point as long as it is not blanketed by the gun or its mounting. Finally it may well be that a set of light signals is required (page 49); to be simple to use and effective, these must I suggest show all-around. One might then envision two fixed marks at 4 and 8 o'clock on the base of the traversing portion. Any of the four heads (2 surveillance, 1 meteorological, 1 light signals) could carry antenna bases if the communications systems required high whip antennas, or other forms of antenna which would not take kindly to being swept aside by the gun; but the telecommunications installation will of course be in the hull.

Traditionally, and even recently in tanks where electronic vision and laying aids and fire control are available, the psychological approach underlying the design of the commander's and gunner's stations has added up to concentration at the conscious level on getting a shot off in the direction of the target. Whether we examine old-fashioned fire orders and the layout of hand/electro-mechanical controls or the crew drills, control engineering and distribution of duties in modern tanks (with the possible exception of Leopard 2), we see what is nothing more than the intrusion of technology into the time-honored way the infantry section commander and his riflemen set about engaging a target. In the British Army at least, highly trained gunnery instructors are so used to shouting fire orders to instill a sense of urgency into the gunner that they are psychologically inhibited from giving a correct fire order quietly over the intercom. The same was certainly true of the US Army and the Bundeswehr a decade back; recent reading and television programs suggest that things have not changed there either.

This is just one rung in the high and massive psychological hurdle that the user has to surmount in moving **from** a turret with an optical primary vision system and the commander at the top **to** an external gun, an optronic primary system and the fighting crew both down in the hull at the same level as the driver. I guess one way to help the user over that hurdle is a radical approach to the man/machine interface and the associated controls. Suppose we say that what the crew are there for is not to fire the gun but to survey the battlefield, to detect and acquire targets and to generate and update a target data output in the form of a line of sight - that is in biplanar Cartesian coordinates with respect to their own position. The on-board computer in its fire control mode adds to this data range (whence target location) and other relevant information like target rates, local "meteor" and the vehicle's own position or movement rate.

This chunk of information adds up to a complete target brief. Given

appropriate downstream processing and transmission facilities, it can be passed to a further processing stage controlling a gun on the same vehicle; to another armored vehicle; to a tactical commander; to an attack helicopter; or to an artillery forward observer or command post. The crew's goal should be to generate the first stage of this target brief. Sure, they will have to take certain further action if they are to use their own gun. We examined the elements of this above. The automated process is a complex one, and the vehicle may have to be maneuvered; but the crew's part in this is extremely simple.

So the controls can be designed specifically to manipulate the surveillance head plus, when necessary, to call up a reticle on the display and **bring the desired point in the surveillance field to that reticle.** Note that this is the precise opposite of conventional gun control philosophy, which is to bring the reticle onto the desired point. Once this psychological distinction is implanted in the designer's and user's minds, the optimal detailed control layout is likely to be rather conventional. The critical case is not in fact engaging a moving target from a moving platform (when the driver will presumably be driving) but maneuvering the vehicle within a position - best done by the commander or his deputy - while tracking a moving target.

For this reason traverse and elevation of the multisensor head must be done by one hand. As I mentioned in the previous chapter, it is doubtful whether joystick control as such is precise enough. The conventional traverse controller (with a spade or pistol grip) mounted so as to rock fore-and-aft for elevation (as on a number of existing tanks) is probably better. Or again, with the man properly seated and his wrist well supported, a small joystick may be the answer. The Chieftain driver's seat being the only thing resembling a properly designed seat I have ever sat in in a tank, I cannot say. In any event, this control can carry a thumbswitch for line-up, armament selection and the rest (see above, and footnote 10), and a squeeze trigger. As a check the weapon or type of ammunition selected must appear in the display when the GUN READY indication comes on. I have to admit to being less than completely happy about the use of only one hand for the key task of aligning the target on the reticle; but the ability of one man to fight the vehicle in static engagements is of such importance to across-the-board effectiveness that the level of performance attainable with a single control unit has to be explored.

The crewman's other hand then becomes available for a joystick for driving override. When maneuvering in a fire position, he will be using the surveillance display, or possibly the strip of the driver's display below it (page 131). This joystick can carry the communications channel selector switch and the press-to-send switch for radio. I am aware of the arguments for a live microphone on radio channels as well as the intercom; but I personally have always felt the risk of a breach of radio silence or security inherent in this arrangement puts the crew under avoidable stress (11).

Banked by the driving override joystick are the most important of the switches not directly associated with firing. Three of these may be worth discussing. One is a RANGING switch for actuation of the laser independently of the firing sequence, either to take range or, at night, to "flash up" a detected target for identification and acquisition. Since this operation can disclose the vehicle's position, its execution must be restricted to the crewman commanding the vehicle at the time by ganging it to the INTER-STATION OVERRIDE switch. The station for which this switch is set has override on control of the weapon mounting, double override on driving, sole access to sending on the radio, control of independent use of the laser (just mentioned), and of a separate LINE-UP switch either for bringing the other station and/or the weapon pod onto line-up with it **or** lining itself up with the other station - in a word overriding control of all main vehicle functions.

This override switch raises some interesting philosophical problems. There are two solid reasons for arranging the system of overrides so that the subordinate station at the time can take over. An evident one is the risk of the commanding station being damaged and/or its occupant becoming a casualty. A less evident one is a situation in which the commanding station is engaged on a tactical shoot at long range and the subordinate crewman is looking after close-in surveillance; this is quite probable even if the normal practice is for the crewman exercising command at the time to pass an acquired target to his subordinate. If the subordinate acquires an urgent defensive target which is threatening his own vehicle or one he is covering, he needs the gun very quickly and should be able to take it except during the actual firing sequence.

Against these arguments, the notion of a subordinate (the gunner or deputy commander) physically taking over control from his superior (the commander) runs entirely counter to army discipline. Analogous situations are the norm in the air and at sea; the copilot when so ordered or the officer of the watch has complete charge of the aircraft or ship unless and until they are ordered to yield it to the captain or some other superior. If the captain is flying the aircraft, or controlling the ship from the operations room, and the copilot or officer of the watch (on the bridge) spots an emergency calling for urgent evasive or offensive action, he must take over physically, informing the captain what he is doing. Common sense suggests that he would be wrong not to, to the extent that a court or board of inquiry would find him guilty of omission. There just has to be enough mutual trust between the first and second pilots, or between officers of the watch and their superiors, for acceptance of emergency intervention by the subordinate which the superior can override only by word of mouth.

My experience is that a similar degree of trust can exist between the commander of an armored vehicle and his senior crew member. Certainly a maneuver squad commander accepts that it is the vehicle commander's job to put him where he wants to be. Sensible tactical commanders do likewise if they can. Nothing is more frustrating for a battalion or company commander than having to control his own tank whenever the loader has to close down; and the same probably goes for the commander of a large platoon. But none of these examples involves a subordinate physically overriding his superior. I have to admit, though, that I can envision an eyeball-to-eyeball situation, of the kind in which some tank commanders are apt to "back mark", where the deputy might lose his nerve and, regardless of the consequences, override his commander and pull the vehicle out of action.

My own view is that the commander and deputy commander should, like first and second pilots, be similar in caliber and hold the same qualifications, differing only in experience and rank. I guess it is up to the commander to exercise his willpower by leadership; and that the deputy should have physically unrestricted override. But I have to confess both that few soldiers may share this view and that I would not have been happy to implement it with the gap in quality between tank commander and senior crewman normally found in the British Army at least. The answer must be, as I have repeatedly suggested elsewhere, large composite platoons which will throw up enough men of vehicle commander quality to fill both fighting stations.

Notes

1 It is fascinating that this split of opinion coincides with the split over tank philosophy and mechanized warfare doctrine. This tends to confirm that the "movement of masses" school regards fighting as secondary to moving, while for the "positional" school fighting is the name of the game. The seeming exception, Israel, in fact tends to clinch the argument; she favors a dynamic doctrine, but is in no doubt about the need to fight because she always has to start by conducting a breakout battle.

2 i e of primary vision instrument and gun.

3 This troop trial was finally carried out - coincidentally by a company of the battalion I earlier commanded - in British Army of the Rhine after I retired. Not surprisingly, the opinion was adverse; but I suspect the cross-fertilization that took place may have justified the cost to both countries.

4 The task of keeping the muzzle inboard (i e so that it does stick out beyond the vehicle's sides) when the gun was not in use could be given to the driver via a gun position indicator - once again a 2-axis situation for him and thus not disorienting; or it could be automated.

5 See Bibliography, **Armor**

6 I say this because the Centurion cupola they have (or at least had in the Six Days and Yom Kippur Wars) was the first to provide a level of vision that could be shown by calculation and demonstration to be genuinely "all-around" in technical terms.

7 HE/HEP fragments more finely than conventional HE shell, so it is more lethal but over a more limited radius and represents the minimal level of fragment/splinter attack.

8 I have to remark, though, that in summer 81, when I learned of this probable simplification, the FRG was in the grip of its third epidemic in ten years of a psychosomatic condition I like to call "Konjunktur-itis" - in other words groundless financial panic.

9 **Antitank**, Chapter 3.

10 For a discussion of this and the control problem based on an actual eighties project, see Bibliography, **Tank**. I wrote these paragraphs and the ones below before that article was published, and have deliberately not changed them.

11 Even with a switched microphone, "Driver right" and its equivalents often go echoing round the net!

CHAPTER 19

Tank Commanding

I deliberately just used the highly controversial phrase "of tank commander quality." I now want to address the question of what this might mean. The only army in my experience which ever consistently produced tank (and tank destroyer) commanders of adequate quality was the Wehrmacht. Certainly poor tank commanding was one of the greatest weaknesses of the Western Allies throughout WWII; and film evidence alone is enough to show that the Red Army more than shared this weakness. Equally certainly the span of ability of tank commanders in a field force unit of BAOR, the Bundeswehr's *Panzertruppe* or 7 (US) Army verges on the unacceptable.

I never succeeded in tracing just how Guderian's appreciation of the problem came about, but there is no reasonable doubt that he viewed the two critical levels of command as the top and bottom - the senior tactical commander (who might also have partial or full operational responsibility) and the vehicle commander. This principle evidently applies to air forces where, during an operation, the role of intermediate commanders is largely confined to inspirational leadership by example. It is less evident in conventional navies, where the various types of unit have graded combat values. And it is the opposite outlook to that of traditionally structured armies, evolved from horsed cavalry and from infantry on their feet. There the critical level of command is - quite rightly - seen as the battalion (1), with a good deal of importance extending one level down. By the same token, while the Wehrmacht saw (and I think the Bundeswehr and the Soviet Army see) the senior tactical level as division and possibly corps, the traditionally-minded army sees it as battalion or maybe brigade (2). It is not entirely easy to distinguish between the effects of doctrine and those of scale; but there does look to be a clear indication that the "apostles of mobility" give priority to the extremes and the prophets of position - to match Field Marshal Lord Carver's phrase - to the middle levels.

As a result the traditionalist armies make little effort to select or train tank commanders as such, in the way they do key specialists like noncom helicopter pilots. I am not at this point advocating selective recruitment for armored vehicle fighting (i.e. "turret") crews. This, I reckon, would result in extravagant upgrading and waste of manpower; it might also give rise to distinctions of status which could not be justified or sustained. Yet a step in this direction may be a foreseeable need for the Americans and British in face of declining educational standards, although it is unlikely to be called for in other advanced countries. For the present, however, it seems reasonable to

hope that a large composite platoon of around fifty recruited from a practicable manpower band would produce the ten or so vehicle commanders and fighting crewmen it needs, and that these would in turn generate the four section/headquarters section sergeants and ultimately the platoon sergeant (3).

In this book, largely for practical reasons associated with the chemical threat, I proposed that armored vehicle crews, once selected, should be given a somewhat gladiatorial, aircrewlike status - something I guess **would** be acceptable if they were seen to be selected from among the "squaddies." Additionally I reckon it may become necessary to provide a third stream of promotion, along with general duties and technical/specialist streams, from fighting crewman through vehicle and section commander to senior instructional posts. This would branch from general duties above sergeant, the one stream concentrating on disciplinary and administrative qualities, the other on control skills, vehicle commanding ability and instructional talent. Some cross-fertilization between these two streams at higher level, including commissioned rank, would evidently be feasible.

I guess I now have to attempt an analysis of the qualities of an armored vehicle commander, and I will do this by discussing his training. As I remarked in the previous chapter, my feel is that the commander and his deputy should be in a first pilot/second pilot relationship in terms of qualifications and experience - in other words both would have the same basic qualification but a commander would have to have more experience and to be qualified on at least two members of the vehicle family. The commander would normally be a sergeant and his deputy a corporal.

It may also be worth reemphasizing that, under the system I proposed in my earlier books, any crewman would be a **trained soldier** who had gained experience in one of the composite platoon's maneuver squads, probably earning himself his first stripe there. Additionally, to be promoted corporal and start his formal training as deputy commander, a man must have passed proficiency tests in all **crew skills** at basic level and at least one at higher level, this on one type of vehicle only. He must likewise have passed the middle level of military educational test (or hold civilian qualifications which exempt him from it) (4). A volunteer on a 3-year engagement with extension options (5) would come up for selection around six months before his option point; and a good draftee on a compressed program could just about reach the standard for consideration before he was due for discharge. In both instances selection would be dependent on extension of service.

Training beyond this level would be concentrated in the central arm school, or possibly in a theater extension of it. I envision a **long basic arm school course** involving as much as six months absence from the unit plus a number of **shorter modules** offering conversion to other members of the vehicle family and/or training to instructor standard in additional skill groups. Since there is nothing unconventional about these modules, we might deal with them in outline first, supposing each to be of 4 weeks' duration.

One pair of modules would train corporals as **maneuver squad commanders and instructors in dismounted skills.** After their spell as maneuver squad commanders/deputy commanders of IFVs, most of these men could probably move, with promotion or otherwise, out of the crewman stream into general duties. Another pair of modules, to be taken by a corporal deputy commander after, say, at least 2 years experience and on selection for promotion, would teach **command skills on a second type of vehicle** plus **an instructor's qualification in a second skills group.** Beyond this point those selected for further promotion

in the crewman stream would undergo further formal and on-the-job training by appointment as arms school instructors.

We now need to flesh out the picture of a vehicle commander by exploring the design of the putative **long basic arm school course.** The traditional view, stated at one time by the British and shared in the past at least tacitly by most other tank-developing countries, is that the tank commander should not become involved in physical functions inside the vehicle. He should confine himself to use of the vision system and radio and to issue of orders to his crew. I do not know how far this was due to analogy with the infantry or cavalry squad commander, to disciplinarianism, to the sacred cow of vehicle configuration, to the state of the art, or simply to elliptical thinking.

In my view the invariable result has been a commander's station with too little involvement for speedy and effective control of the vehicle and too much for the efficient exercise of tactical command. We need then to spell out that the subject of this chapter is a noncom who may be supported by a deputy commander or may be controlling and operating the vehicle while the maneuver squad is dismounted or a tactical commander in the sister station gets on with **his** job. As the Swedes like to emphasize when justifying the third station in S Tank, between 33 % and 50 % of tanks in a conventional organization contain a tactical commander of platoon or higher level or a deputy tactical commander.

The notion of keeping the commander at least psychologically remote from the nitty gritty of what goes on inside the tank is the complete opposite of the equivalent philosophies in small naval units and aircraft. These put the commander right in there pitching, giving him the means to perform all or most of the key control functions himself. Often, though, he does this at one remove; for instance he aims the gun, missile or torpedo by pointing his craft at the target. This is also the philosophy of S Tank; but the limitations of that vehicle serve to emphasize that the intimate, complex and ever-present factor of ground makes commanding an armored vehicle a different ballgame than operating a craft in a uniform fluid medium.

A different balance evidently has to be struck. This is why, in the previous chapter, I suggested that at least the top half of the commander's body should turn relative to the hull even when technological aids make this physically unnecessary. It is also why, in the context of duplicate command stations, I expressed a preference for establishing the line of sight by moving the surveillance display field **to** a "fixed" central reticle - the opposite of the conventional system of laying (6). By the same token a separate driver is indispensable, and the more independently he can operate the better - except of course in detailed maneuver within a fire position, or when the commander or his deputy is spelling the driver during a long move. The underlying need, though, is for flexibility. The commander should be able to choose whether to execute a task himself; or to share it with his deputy; or to delegate it fully to his deputy or the driver.

Out of this discussion come two main themes of training. The first of these is **appreciation of ground.** Excellent map reading is not enough; the need is for mounted fieldcraft. I am convinced that the best form of training is orienteering, some of it on foot and some on motorcycles, with the added element of penalizing exposure to view on some or all sections. Evasion and escape exercises in hilly terrain likewise develop appreciation of ground and cover at the minor tactical level. Additionally they keep men fit and are an aid in the fostering of the second theme, **command skills.**

This is a key area. Most Western armies look to be having great and increasing difficulties in selecting and bringing on junior noncoms. In a social climate which rejects authority to the point where many fit to wield it do not want to, I for one reckon the conventional moralistic/chauvinistic approach is likely to cramp swiftness and independence of mind without providing strong or lasting motivation. A healthier and more promising approach is job satisfaction. The young noncom needs to be put in an environment where he sees he can only exercise his evolving skills as leader of a small team.

By the same token he needs a training environment in which he can come to appreciate the judgment of priorities involved in performing a multiskill task in a complex situation. I wrote elsewhere that a small yacht was the ideal environment for training armored vehicle commanders in decision making and leadership. Sailing at the offshore cruising level is expensive, not always available and not to everyone's taste. But it offers a known situation from which can be derived training methods employing some other mix of terrain, climate and basic vehicle to produce the essential element of real danger to life and the same distinction between calculated and stupid risks.

Leadership techniques link with the third theme, **communication.** This also covers instructional technique, effective use of the radio and methods of briefing, debriefing and reporting. I see the first 2 modules (8 weeks) of this long course devoted entirely to these three themes, with about equal emphasis on each and for the most part using methods which straddle all three. The next module, probably after a spell of leave, would nominally be split between these three broad themes and the fourth, **technical training,** but in fact reintegrate this with the first three by using group projects and mutual instruction to impart the requisite knowledge. The goal of the technical module would be comprehensive user knowledge of the commander's and deputy commander's stations on one type of vehicle, with an introduction to the other main types. I see no reason why the newly promoted corporals should not be mixed at this stage with trained and experienced commanders on the short courses discussed above.

The final leg of this long course would be devoted to **crew training and tactics** and carried out on school vehicles organized into normal subunits. Here again the young students would be mixed with more experienced noncoms attending one of the conversion courses; and I see no reason why platoon and company commanders' courses should not also be integrated. Ideally his tactical phase would culminate in an exercise covering deployment, lying up under NBC threat, an operational move, a simulated combat phase and a battle run.

Tank commanding is an art and therefore difficult if not impossible to analyze and quantify in objective terms. I dreamed up a training sequence because I reckoned this to be the best way of identifying and putting in perspective the various human qualities and skills which practitioners of this art require. Military readers will hoist in the message, though they may disagree with parts of it. I frankly do not know how to find common ground with analysts and designers on this topic. Maybe the best way is through their leisure pursuits. Those who sail or climb mountains, take part in expeditions with an ecological flavor, or do langlauf skiing, orienteering, horseriding, "motocross" (or the like) or rallying will, I guess, have gotten the feel of what I am trying to say. For commanding an armored vehicle has a deal in common with all of these.

As a guideline and **not** as a rigorous or definitive approach, it may be helpful

to clarify the commander's tasks like this -

those which he must perform entirely but call for no physical action other than speech - e.g. surveillance and reporting

those which he must perform or at least initiate by physical action - e.g. engagement

those which he must be able to intervene in and modify while they are in progress - e.g. engagement, driving

those which he must monitor continuously and in which he must be able to intervene retrospectively - e.g. troubleshooting

those which can be left under fully automatic monitoring between checkouts - e.g. fire extinguishing system.

Trouble is, tasks or functions shift from category to category in different situations. This is why I have structured this book under the main heads of living, servicing and fighting. Priority must evidently go to fighting, but only after the provision of living conditions and servicing procedures which ensure that crews and their vehicles enter combat fit to fight.

More broadly, I might try to say two things about crew station design without myself being too sure what either of them means, specially what they might mean in terms of design parameters and hardware characteristics. All crew stations need to be designed as extensions of the human senses and muscles, leaving the human operator at the center of the scene. All stations from which command of any kind (including command of the vehicle) is to be exercised need to be so designed as to keep the commander's mind divorced from the vehicle while integrating him closely and efficiently into all the subsystems he needs to use. I shudder to think of the tactical consequences of putting the tank commander into a deathbedlike trance in which he feels his spirit to be floating above his body and observing its actions detachedly. But that folklore image may not be too bad a one for the designer to have before him.

Notes

1 Or in the cavalry the British regiment, United States squadron.

2 In fact, I reckon the British see it as battalion/battalion combat team, with brigade thinking operationally; the Americans as a full colonel's command (regiment or brigade).

3 After confusing myself and many reders with the nomenclature of the extra level I introduced in **Tank Warfare** and **Mechanized Infantry**, I settled in **Antitank** for - platoon, section, crew/maneuver squad. I also stipulated that the platoon sergeant should be of first sergeant quality.

4 As far as I know most armies operate a three-tier system of education tests, though syllabuses and levels differ considerably.

5 Or the converse - a long service engagement with option points for discharge.

6 It may be worth recapitulating here that the commander (or his deputy) establishes the line of sight in terms of azimuth and elevation angles relative to the horizontal longitudinal axis of the hull. These angles then become one of several inputs by which the on-board computer in its fire control mode determines the correct attitude of the bore axis. The other manual input is of course the selection of armament and ammunition.

CHAPTER 20

The Command and Control of Mechanized Forces

We looked at the physical problems of command vehicles in Chapter 7 and at those of commanding an armored vehicle in the chapters immediately preceding this one. The broader subject of command and control looks to be far removed from the nitty gritty of armored life and combat with which this book is mainly concerned. Maybe, though, the very fact that these two aspects of mechanized warfare can strike one as being unrelated to each other serves to explain why mechanized operations have so often failed to produce the results expected of them. Maybe disunity of thinking between two higher levels of command leads to a deeper-seated, though less immediately conspicuous kind of disorganization than it patently would at the lower tactical levels.

One can certainly see the effects in commercial organizations, where disunity not just of doctrine but of purpose is apt to extend upwards to the highest levels - and here I am thinking of internecine strife within management, not the management/union interface. This is not the place for a deep plunge into military history, but one might first recall the shining exception - Israeli armor. The Israelis made some costly mistakes, notably in the early stages of the Yom Kippur War, mainly because of a belief in the fighting power of tanks inadequately supported by infantry and artillery in face of a high-density positional defense. But their armor, an avowedly elite force, has never failed to achieve the military goals set it; the political soundness of these goals is another story.

Heavily as the bulk of British armored thought leans towards the positional, disunity of doctrine has hamstrung British armor right through from 1916 to the present. Cambrai (1) apart, some of the most striking examples of this are to be found in the North African campaign prior to the arrival of Montgomery; he at least imposed unity, albeit the unity of the boot rather than the track. The history of tanks in the US Army shows similar, maybe even more pronounced conflicts and swings of opinion. It was largely clashes of doctrine that crippled French armor in 1940 (2). It may be fair to say that unity of outlook from minor tactical up to operational level brought Guderian's *Panzertruppen* their successes, while lack of logistic appreciation and, later, disunity at strategic level underlay the course of operations on the Eastern Front from the failure to take Moscow onwards. Certainly the Bundeswehr lays great stress on unity of doctrine. Monolithic and formidable as it may look, the Soviet Army is now on the return swing of its second cycle of the track/boot pendulum (3) and wracked by argument between four schools of thought on armored doctrine with differing views on command and control too.

We can maybe distinguish five approaches to the command and control of mechanized forces, in increasing order of "tightness" -

Minimal control after breakout from operational depth - an attempt to put into one phrase the doctrine favored by the Soviets in the decades after WWII, in which the emphasis is on randomness and momentum and very deep objectives are set (4).

Directive control - as favored by 7 (US) Army and BAOR in the tactical nuclear heyday of the fifties and sixties, in which the subordinate is left to interpret a directive stating his superior's mission.

Mission-type control (5) - as preached by the Bundeswehr, in which a statement of the superior's mission is amplified by spelling out the subordinate's mission and the constraints under which he must execute it.

Forward command - as practiced by the Wehrmacht's *Panzertruppen*, in which the senior commander issues orders based on direct observation and may actually assume command of a lower formation or unit at the crux of an operation.

Detailed-order tactics (5) - as preferred (more or less discreetly) by the American and British Armies and increasingly favored by the Soviets, in which every least move is dictated or at least influenced from the highest level practicable.

Before homing in on the West German and Soviet doctrines we might note en passant that the Wehrmacht purportedly preached mission-type control but, frequently and with notable success, practiced forward command. I can see the structural and political reasons for which the Bundeswehr, in theory at least, regards forward command as anathema; and I go right along with the idea that, in training, junior commanders should not just be allowed to make mistakes but actively encouraged to experiment. Equally, with violent conflicts of views between different levels - in peacetime different generations - of officer, I can appreciate Anglo-American sensitivity to the overt practice of forward command as opposed to the application of pressure downwards and "delegation upwards."

Yet in war the name of the game is winning, both for its own sake and because success is normally the surest way of minimizing casualties. In most mechanized engagements there is a crunchpoint at which speedy and correct implementation of a certain course of action has a decisive effect. By definition the subordinate commander will not have the same combined stock of talent and experience as his superior. Even if he had this, the fog of war is so thick at low level that he may not be able to see the nearest tree, let alone the wood.

Surely it makes sense for a respected senior commander to see to it that the right thing is done at the right time. By being on the spot he gets the true feel of the situation, the thing that makes folks go to ballgames rather than watch them on television. Additionally he exercises inspirational leadership on the troops who are going to execute the critical mission. Above all, he can bring his full professional judgment to bear on the form and timing of this maneuver. However he intervenes, he is going to tread on somebody's toes, at least those of intermediate commanders who are (quite properly) not there. So I cannot see that the manner of his intervention matters too much.

As a host of hackneyed quotes demonstrate, all the "great captains" of history

have exercised forward command in the manner appropriate to their times; otherwise they might have deployed their talents but could never have exploited the gift of luck that made them great. Maybe, never having been to Sandhurst, I lack a sense of military propriety, but my views on forward command are rather simple. If a higher commander is not professionally superior to his subordinates, he should not be a higher commander. If he is, protocol should not be allowed to stop him winning the battle. I just cannot see any contradiction between mission-type control and forward command as long as the mutual confidence on which mission-type control rests is genuinely felt by all concerned.

But before probing the Bundeswehr's doctrine deeper, let me stress that the command and control system to which the Soviets seem to be moving could prove to be a critical weakness in the capability of their mechanized maneuver force. With a slight twist of the definitions I used above, I would describe this as **"detailed-order tactics by rear command."** It is not difficult to describe or to envision. In Soviet high intensity operations the highest tactical level is probably army (formerly corps), with front (6) as both the operational level and the operational/strategic link. In this event there are five, maybe six levels of command between the army commander and the vehicle or maneuver squad commander. Despite this, the low staffing levels of Soviet headquarters; the enormous effort going into the provision of a sophisticated communications and data transmission system (at least from battalion upwards); the doctrine that seems to be coming out on top from the present controversy; and the concern over lack of creative command talent among even hand-picked Soviet officers all add up to an image in which the army commander uses a television monitor and a computer terminal to move individual tanks from one piece of cover to the next.

On this scale, advanced electronics evidently provide one of the three planks on which "detailed-order tactics" rest. Another is, naturally, detailed orders issued in advance. A third, much beloved of the Americans too, is the standing operating procedure or SOP. The ethnic and cultural diversity of their manpower pools in fact faces the American and Soviet training organizations with much the same problem. I recall an American officer whom I was teasing about rigidity of tactical teaching saying to me: "You don't know the problem. Try to imagine yourself training a European Army." I hoisted the message. By contrast, I recall arguing with an American officer who was a good friend and valued colleague at a mess night at the Royal Armoured Corps Conference. I drew on the back of a menu card a mirror image of one of the tank-infantry tactical moves illustrated and spelled out in the then current US Army manual. (As I recall the manual showed a small right hook and my sketch a left.) Even later, when I showed him the original, he could not spot the link. I tell this story to illustrate the danger of SOPs, with the strong feeling that my friend's Soviet counterpart would not even have admitted the possibility of a left hook.

Up till now I never took too seriously the view that Soviet junior and middle-piece officers are incapable of operating to good effect in the relatively broken terrain of central and western Europe. But the course of events in Afghanistan and the latest trends in Soviet command techniques add a deal of weight to this contention. It would be wrong, though, to belittle the SOP or to regard it simply as a means of knocking heterogeneous armies into shape. If the Soviet Army really **is** capable of attacking off the line of march with a battalion combat team, or of snorkeling a major water obstacle as if it was crossing a bridge on a turnpike, this is thanks to its SOPs.

With full SOPs and norms for scales of artillery support, a complex operation can be launched rapidly - even if not quite off the line of march - and securely. Orders can be brief, initially even just a codeword, grid reference and time. With deployment under way, there is time to work out and distribute by secure means ground-related details like junction points, boundaries, bounds and target lists. Additionally knowledge and observance of SOPs is a key to the ease of regrouping with which the Soviets make so much play. If you do everything by numbers, life becomes rather simple. Big brother's task is rather simple too, not unlike that of an American football coach during a game. He just punches the numbers into his computer terminal (7).

All this is credible, because it is much more Russian - and I mean Russian, not just Soviet - than a cry of "Go West, young man" and a wave of the hand to launch a combat team commander across the Weser headed for the Rhine. I am beginning to wonder whether this attitude really ever did prevail. But Soviet practices in the command and control of their mechanized maneuver forces are so important, so controversial and in such a state of flux that I would just like to put the situation on record as I saw it at the time of writing (summer 81).

For a Westerner studying the Soviet forces, delving back into history is far harder than evaluating the current or recent past state of affairs from the ample published material now available. But I am beginning to wonder whether Stalin's purge of the Tukhachievskii school in 1936/37 may not have been at least partly due to the incompatibility of their teachings on mechanized infantry with the "detailed-order tactics" beloved of Stalin and of the senior infantrymen of his day. Certainly film from the time of the battle of Stalingrad (8) shows the tanks moving like puppets on overly short strings. It may be worth recalling that the bulk of the Soviet power generation of the thirties and forties spent their formative years under the czarist regime. For the concept that was to dominate Soviet land warfare doctrine in the last two years of WWII and seemingly the three decades that followed it seems to stem right from the roots of Marxism and form a thread linking the structure and doctrine of the Soviet Union's organized forces with the teachings on revolutionary warfare of Mao Tse Tung, Ho Chi Minh, Che Guevara and their successors.

I have yet to discover, though I mean to do so if I can, just how a doctrine based on randomness - on the unpredictability of the location, nature and outcome of individual events - ties in philosophically with the deterministic nature of Marxism-Leninism. The clue may well lie in statistical theory; if so, though, it is intriguing to say the least that the supplanting of the linear causality of classical physics by probabilistic concepts led many physicists towards theistic religion. At the practical level, it is important, despite their apparent similarities, to distinguish this Soviet doctrine from blitzkrieg. By contrast, high-risk military doctrines seem to be a common factor among regimes in the immediate post-revolutionary stage of development and to be abandoned as the new society settles down.

Now the Soviet Army is suffering from a battle for supremacy between four schools of thought. The one I just discussed might be described as that of "old tankers" - the "heavy break-in" followed by the random breakout. The "young tankers'" extension of it calls for a surprise attack with a tank-dominated maneuver force rolling over a nuclear and chemical carpet to and beyond the Rhine, to reach Bonn, Brussels and the like within 24 hours. To my mind this option must be as attractive to the Warsaw Pact as it is dangerous for NATO. Then there are what one is tempted to call the "young turks" - the BMP enthusiasts with their "swift, incisive slashes." All these schools of thought evidently favor a type of command and control ranging (on my categories above) from "minimal" through "directive" to the borderline of "mission-type."

Certainly the "young tankers" oppose restrictions aimed at the minimization of tactical risk. They believe - in my view not without cause - that surprise and sheer speed will inhibit the opposition's tactical and operational response and achieve a strategic goal before world political opinion can react.

In complete contrast is the view of the seeming winners, the "old infantrymen." They advocate extending the concept of the combined arms combat team upwards to army, maybe even front level; and in subjugating armor and aviation alike to the discipline and tempo of a combined arms operation. Their outlook seems to resemble very closely that of Eisenhower and Bradley in WWII, with emphasis on a broad front, tidiness and the massive, highly coordinated employment of material to minimize risk and casualties. To my eyes this approach gives NATO its best if not its only chance of stabilizing the situation within the geographical confines of the West European theater. Yet again, the deployment of "theater nuclear weapons" by both sides favors the "young tankers" because it once more makes the use of nuclear weapons thinkable (9).

It may well be that doctrines we see as conflicting are in fact complementary, that the "detailed-order tactics" of the combined arms army will prevail until a substantial penetration to "operational depth" (10) has been achieved and secured; and that the "young tankers" and "young turks" will then be allowed to cut loose in breakout and pursuit roles. This complementarity makes sense as a response to increasing loud and public murmuring by the "young tankers" of the Bundeswehr about "preemptive attacks" and "operational counter-offensives" across the Elbe.

Certainly "mission-type control", as preached though not necessarily practiced by the Bundeswehr, represents a commonsensical, middle-of-the-road, politically unimpeachable approach. To see whether it also represents the best way of handling highly mobile maneuver forces we need to probe the rationale of command a little deeper. I offer no excuses for reiterating points I have made in earlier books, for by happenstance I recently gained a new insight into this problem by envisioning it in terms of a spatial (three-dimensional) Cartesian model (11). Readers will be familiar with the two-dimensional grid ("personality grid," "management grid" and the rest); they may find it easiest to envision the spatial model as a Halloween lantern hollowed out from a pumpkin. Any point within this globe describes a particular combination of command techniques or qualities.

Here I must fall back on what I have written or said in public elsewhere. We can identify one axis of the model with the problem which we addressed so far in this chapter and which I will now summarize as **"loose rein - tight rein"** (fig 18). Another, briefly aired above in the Soviet context, straddles the dividing line of the two major schools of thought on mechanized warfare. It is the extent to which mobility is still translated into actual fighting power, as it patently was in the chariot or cavalry charge, by the direct application of dynamic forces - kinetic energy, momentum and rate of change of moment. This opposition can be described as **"dynamic - positional."** Related to the fact that these two schools of thought can coexist is the question of the relative importance of the psychological and the physical. Nobody can dispute the physical nature of war, but how far the outcome of a battle, campaign or war is determined by the true physical situation and how far by the images in the opposing commanders' minds is another thing again. Whence the third axis - **"psychological - physical"** (12).

At this point I would invite the reader to test this model with regard to both qualities of the commander and techniques of command against historical situations with which he is familiar. Unfortunately it is impossible to "blob in"

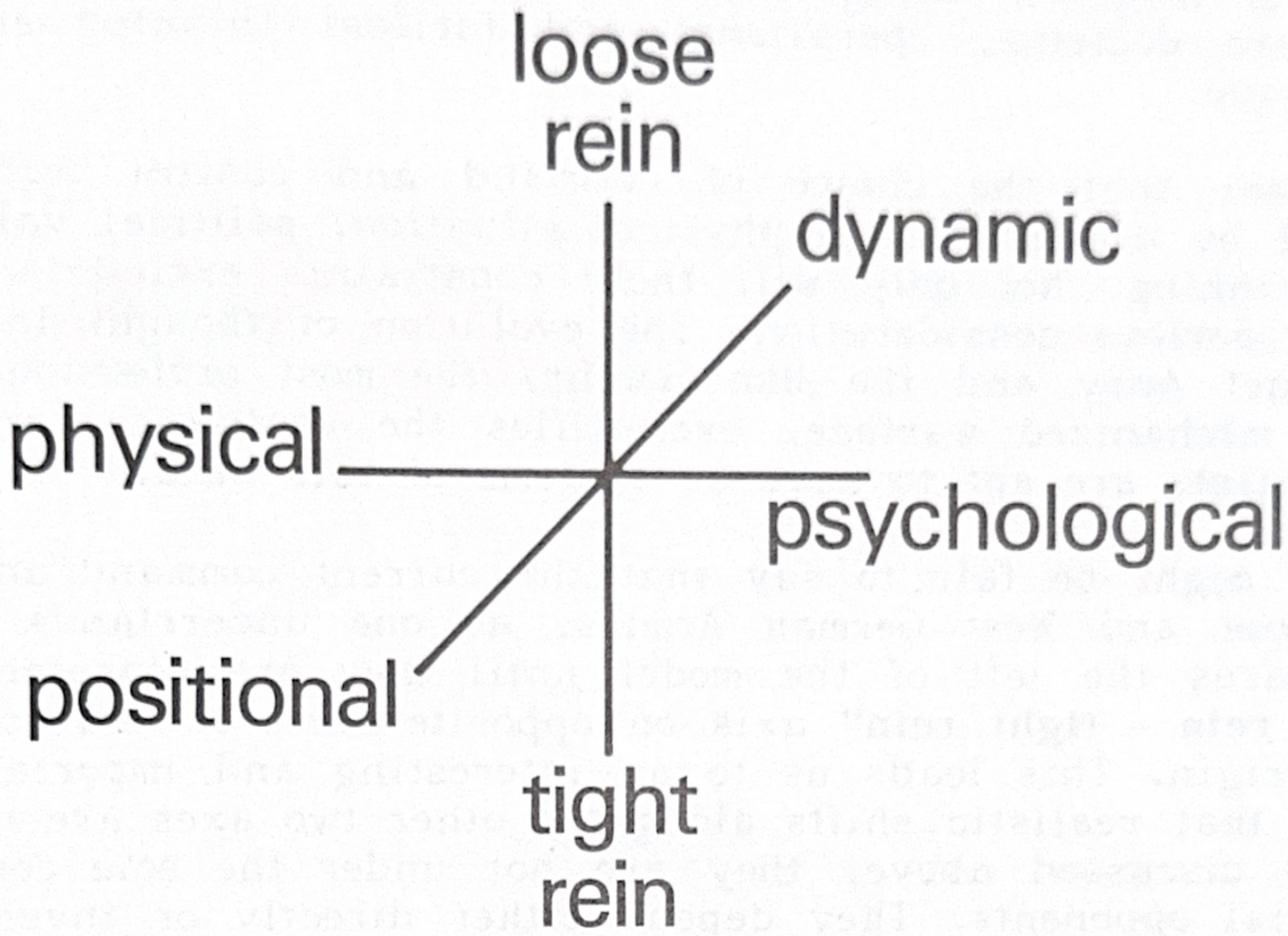


Figure 18. Command techniques model

points on a spatial model within the confines of the printed page; but I suggest, for instance, that the Anglo-French command of WWI is on the lower left periphery; the Eisenhower/Bradley approach of WWII between that and the center; blitzkrieg well to the right of and slightly below the center; and the purported Soviet "minimal control" doctrine well out towards the top right.

Theoretically any point within the model represents a possible command and control doctrine. But the elementary examples above suffice to indicate a correlation between the extremities shown lower left and those at the upper right; and thence a polarization towards "detailed-order tactics" on the one hand and "minimal control" on the other. In fact the five categories we listed earlier lie in a progression from the upper right to the lower left of the model, with the Bundeswehr concept not too far from the center.

Again, because war is physical, objective physical realities impose constraints on the effectiveness and relevance, if not the feasibility, of the command technique represented by certain zones of the model. Technological advance in the form we have experienced and can predict tends as a whole to reduce the importance of chance and thus to shift the optimum left and downwards. By contrast mobility moves it in the opposite sense, and the effect of telecommunications pulls both ways along the **"loose rein - tight rein"** axis. Taken together, though, the state of the art, climate and terrain present a unique physical situation to which the commander must surely adapt his philosophy and his techniques.

The sensitivity of advanced societies to physical interference and the now undisputed sounding-board effect of the media are other factors here. So are the geographical and/or politically determined dimensions of the theater, its

distance from major strategic objectives, and the politico-economic value of its own terrain. In the NATO center this last aspect has, as I remarked elsewhere, forged lookalike tactical doctrines from the very different philosophies of the West Germans on the one hand and the Americans and British on the other. Here we come upon a further constraint too. Since command and control technique is largely - though not wholly - a tool for the implementation of a land warfare doctrine, operational and tactical thinking evidently influence that technique.

We see then, that the choice of command and control technique is heavily constrained by a unique total physical situation, political value judgments and military thinking. Not only will these constraints exclude whole zones of the model from serious consideration. The evolution of thought in the officer corps of the Soviet Army and the Bundeswehr, the most professional of the world's armies in mechanized warfare, exemplifies the centripetal or normative effect that constraints are apt to have on systems of this kind.

I guess it might be fair to say that the current command and control systems of the Soviet and West German Armies, as one understands them, have been forced towards the left of the model until they are represented by points on the **"loose rein - tight rein"** axis on opposite sides of and roughly equidistant from the origin. This leads us to an interesting and important point. Even to the extent that realistic shifts along the other two axes are not limited by the constraints discussed above, they are not under the sole control of either of two potential opponents. They depend either directly or inversely on the view each side takes of the other's mechanized warfare doctrine and command philosophy.

The only path along which an army has real freedom of movement is the **"loose rein - tight rein"** axis. Thus our sphere of possible choices of command philosophy and technique is reduced to a cigar-shaped ellipsoid of realistic and effective solutions, formed round the **"loose rein - tight rein"** axis. To my mind at least, the Anglo-American approach to command and control in mechanized warfare lies well to the left of this smaller zone and near its lower extremity. This discussion does confirm, though, that the **degree of control**, the parameter I used in the early part of this chapter, is indeed the critical one.

I wrote elsewhere that it seemed to take the full career span of an officer rising to the highest ranks, thirty years or more, to introduce any major innovation into an army. If this is true of physical changes, like the replacement of the musket by the rifle, it has to be an understatement where radical changes of structure or thinking are concerned (13). Apart from occasional opportunities for a fresh start - such as the Bundeswehr enjoyed after Germany had paid a terrible price for it - i suspect that a change in basic thinking on command technique takes the best part of **two** career spans to implement. The innovators need to rise to positions where they can influence the training of cadets or young officers. Then those youngsters have to get to key command levels.

Additionally organizational inertia is compounded by individual and collective conservatism in matters of this kind. Probably this is why controversy in the Soviet tank world looks to be so heated and prolonged. Even if it is feasible to arrive at a combination of land warfare doctrine and command and control technique which matches the physical realities of the timeframe, this technique certainly cannot respond to transient changes unless flexibility is deliberately built into it. For it is self-evident that various levels of nuclear and/or chemical threat or actuality, the different types of combat and even tactical developments call for or indeed impose changes in the techniques of command and control.

Likewise the critical aspect of command changes from day to day, hour to hour or even minute to minute. Now it may be leadership, now tactical judgment, now precision of timing, now controlled variation of tempo - and most of all turning a piece of luck to one's advantage. Again, in the murky ebb and flow of battle anything laid down in advance, be it SOP, detailed order or "constraint," becomes a hostage to fortune. Even a tactical, and very occasionally an operational **mission** may become irrelevant before it can be promulgated.

As I understand it, the Bundeswehr's "mission-type control" is firmly anchored a fair distance along the **"loose rein"** half of the axis; as a necessary consequence the mission and constraints, once laid down, are sacrosanct until rescinded. The system **looks** flexible because it was designed to conform to the accepted military virtue of flexibility. But as preached - and let me reemphasize not necessarily as practiced - "mission-type control" is just as lacking in real flexibility as the "detailed-order tactics" its protagonists hold up to ridicule. More important still, it is too standardized to allow individual commanders to make the most of their strengths of skill and character. This is why I reckon that "mission-type control" may be a compromise - and a cosmetic one at that - rather than an optimum.

We can now firmly identify certain elements which any system of command and control is apt to contain -

SOPs

statement of superior's mission

laying down of subordinate's mission

giving of orders for, or laying down of constraints on execution of subordinate's mission

intelligence input

dissemination of various special coordinating details (which need not concern us further here)

Additionally we can assert that the system must contain real flexibility of two kinds. It must be able to adapt itself to a wide range of situations and to respond effectively to changes of situation which will often be extreme and may be traumatic in their scale and pace. And it must allow commanders at the critical tactical and operational levels to do their own thing.

> Brigadier General A must be able to slap his men between the shoulder blades or exhort them on the video, then lead them into battle head-and-shoulders out of his hatch, helmetless and with pistol or carbine waving. What time his deputy and staff get on with the mundane business of fighting the battle.
>
> Brigadier General B must be able to sit tight-lipped in his command vehicle, with map, felt-tip and calculator, orchestrating every subunit move with the intensity and uniqueness of a von Karajan; what time his subordinates down through the ranks know that he is giving them the best chance of winning and the least chance of dying.

As the crunchpoint approaches Lieutenant General X may turn away from the map and the display unit, tell his orderly to pour him a vodka and tonic, and stroll through the rose garden of his chateau of the moment sipping and sniffing away until suddenly he turns on his heel and calls "Launch the reserve - Plan 2." This will probably have been the first occasion within several days in which he has allowed military activity to interfere with his life-style. Yet everybody under his command knows that his decision will be correct and - and he expects - will have done everything that needed to be done.

Lieutenant General Y's chopper is vaulting the hedges and ducking under the power lines, swerving occasionally to avoid a burst from a ZSU23/4 as it flies down the line of contact until he issues the key order by firing a signal pistol, maybe flourishing it at the nearest Hind.

We may, indeed should laugh at these stereotypes; but we should not belittle them. Any one of them may turn out to be a battle-winning, even a war-winning figure - **provided the system allows him to do his thing and compensates for the things he leaves undone.** But none of them, nor any more typical commander either, will become a battle winner if, when he senses or intuits a crisis which makes nonsense of his plan and the orders he has issued, he sits back and murmurs "What I have written, I have written." Nor if, after due deliberation, he tells his staff to pass complex new orders along channels which are probably clogged with information if not jammed by the opposition's electronic warfare techniques. He needs to decide where the critical spot is; to get there; to hoist in the full smell of the situation; to grab whoever he finds there and somehow to set them about taking some kind of holding action while he puts a contingency plan into operation or makes a new one.

Reverting to our model, we see that both these kinds of genuine flexibility are offered by one and the same thing - **freedom to move along the "loose rein - tight rein" axis.** This I believe to be the real meaning of **forward command,** as practiced by Alexander at Arbela (14), Wellington at Waterloo, Rommel on the Meuse, von Manteuffel at Targul Frumos and Patton in his advance from Luxembourg across the Rhine - the art of being on the spot when needed and making on-the-spot interventions that are as occasional as they are decisive.

This flexibility, though, will only remain genuine if it is not trammeled by restrictions laid down in advance. I do not think it really matters when the chips are down whether this is done in the positive form of orders or the negative one of constraints, whether in the general form of tactical SOPs or the particular one of operation orders. The form of command which I earlier called **directive control** was devised by the Americans and British to cope with the most violent, intense and traumatic form of warfare then envisioned - tactical nuclear war. Maybe mechanized warfare of the nineties is unlikely to be nuclear. But it may well be chemical; the history of recent high intensity operations suggests that it will be extremely violent; and the predictable state of the art indicates wide scope and high tempo accompanied by loss or severe hindrance of radio communications. I suggest that **a combination of directive control and forward command,** techniques that straddle "mission-type control" but are distinct from it even when combined, offers the best chance of meeting this need.

Here the subordinate commander is given a mission but has authority to modify or radically change it within the framework of the superior's mission.

Evidently the forward command option provides the superior with a chance to intervene at any level whenever he needs to and can. But the absence of both detailed orders and constraints combines with flexibility of subordinates' missions to impose an acute need for coordination.

Just as tactical SOPs can become snares for an astute opponent to set, so SOPs have two extremely valuable functions. One resembles the role of operational analysis and data processing systems in narrowing the zone in which subjective value judgment has to be exercised in making and executing a decision. It is to remove from the concern of high-grade human efforts the nitty gritty of command - dissemination of intelligence, staff-level coordination, logistics and telecommunications detail. All this can be standardized and automated on a management by exception basis with no loss of effectiveness whatever.

The other, as I have stressed elsewhere, is to lay down ground rules which provide a framework for coordinated freedom of action by commanders. In most instances it matters little what these rules are, as long as they are understood and observed. For example, all levels of command could be made responsible for liaison to their left and given freedom to intervene across their left boundary in emergency. Presence of the enemy within one tactical formation's or unit's direct fire zone could give that formation priority call on all artillery and attack helicopters within range or reach. There is ample precedent for broad rules like this in the air defense field and in air and naval operations. The need is simply to attune land forces to the realities of high-performance mechanization.

A chapter like this cannot hope to do more than open up arguments along new paths in addition to well-trodden ones. I have deliberately attacked complexes of thinking on land warfare doctrine and command techniques which are probably entirely valid and workable - but only with the goal of making them still more so.

Nonetheless there is one theme that has I guess run through this book from building accepted discipline to keeping fit buttoned-up to design of crew stations to command and control - and about which I am adamant. Even far-out sci fi writers do not venture to look forward to the day when command in war will be handed over to robots and its conduct to unmanned craft and vehicles. Anyone who did would find their program drop clean out of the ratings. Seriously, though, no substitute for the human commander, the piloted aircraft or the manned ship or vehicle is yet in prospect. As long as we expose commanders to extreme responsibility and crew to extreme risk, we must make sure that the man is and is seen to be right there in the center of the primary control loop where he can pull something out of the bag. The task of technology and biotechnology is to provide an extension of his powers and faculties, not a surrogate for them.

Notes

1 November 20, 1917

2 If anybody ever doubted this, de Gaulle's memorandum of November 11, 1939, to the commander-in-chief and chief of staff of the French Army, dispels this doubt (See Huard, Paul; **Le colonel de Gaulle et ses blindes** (Paris, Librairie Plon, 1980)).

3 The first being represented by the rise and fall of Tukhachievskii in the thirties.

4 Research for a future book is in fact giving me increasingly to wonder whether this "Soviet doctrine" which provided NATO with its stereotype threat for two decades was not just an artifact of Western, notably United States, intelligence.

5 Literal translations from the German as offered by the Bundeswehr, but the second one particularly apt.

6 In Western terms "army group." Recent authoritative sources, both Soviet and secondary, leave little doubt that the "corps" level is no longer included in the normal chain. A Soviet army is about the size of a Western corps; and divisions are referred to as "tactical formations" (lit. "large units").

7 One of the things I as a British armor man find alarming about the "active defense" doctrine developed and practiced by MG Livsey (U.S. Infantry) is the numbers game.

8 Winter 1942; the city is now called Volgograd.

9 The hypothesis underlying this remark is that, once the Americans deploy IRBMs ("cruise" and Pershing) in Europe to face the SS20s deployed in Warpac satellites, the superpowers can escalate to a nuclear exchange in Europe without risk to their metropolitan territories.

10 Radzievskii's **Tankovyi Udar** (1977) lays great stress on this concept.

11 I am more and more struck by the way a few simple models provide insights into an enormous variety of complex problems. I hoisted in the wide applicability of this one (as opposed to the familiar "grid") while translating a thesis on French advertising jargon by a German linguistician.

12 "Psychological" here comprehends Napoleon's dictum, which is essentially concerned with leadership, but extends considerably beyond it.

13 A striking example of this arises from the US Army's studies of its 1986 force structure. The final evaluation conceded the force of the arguments for composite tank-infantry battalions, but rejected this change because "the Army was not yet ready for it." (See Bibliography, **Armor**).

14 Also referred to as Gaugamela, 331 BC.

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NOTE

The factual information on which this book is based is of two types. On the one hand there are the military requirements and technological constraints; on the other there are the biotechnological, physiological and neurophysiological inputs.

The first I documented exhaustively in *Antitank*. I would refer readers to the Bibliography of that book and the additional sources listed in many of the entries in that Bibliography. I have included below only a few new references which are directly relevant.

The "scientific" input - to use that term a shade loosely - is vast and varied, covering a span of three decades and a number of disciplines old and new. Over this period many of the establishments concerned have passed into and/or out of existence, or have changed name and/or location. Additionally much of the know-how has filtered through to the armored vehicle field from those of aerospace, production engineering and automobiles and other consumer durables. Any attempt to document this material would be a major project in itself and probably lead the reader on a wild goose chase. I have therefore listed some of the main focuses known to me at which information of this kind is held and/or listed in such a way that it can be retrieved.

There are of course a number of excellent formation and regimental histories, as well as individual memoirs and diaries, which provide a general background for the reader coming new to the field. But Bren Adan's book (overleaf) is probably the only first-hand account of major armored operations recent enough to teach direct lessons for the future.

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